

IAQ GUIDELINES FOR OCCUPIED BUILDINGS UNDER CONSTRUCTION



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SECOND EDITION – NOVEMBER, 2007



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**4201 Lafayette Center Drive
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**SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.**

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FOREWORD

In an effort to provide SMACNA contractors, architects, engineers, building owners and managers, and the general construction industry with a researched, practical publication to assist in maintaining acceptable indoor air quality during building renovation, SMACNA's Building Services Committee developed the first edition of the *IAQ Guidelines for Occupied Buildings Under Construction*. This manual has its roots in a workshop that took place during the IAQ 1993 Conference that was co-sponsored by SMACNA and other professional organizations. As the conference progressed it became clear that, other than the combined experiences of the presenters and other specialized professionals in attendance, there was little published technical guidance that dealt with the potential health hazards and annoyances related to carrying on construction activity in occupied buildings.

This second edition of the IAQ Guideline has been updated and was passed through an additional review process using a canvass review that meets SMACNA's American National Standards Institute (ANSI) accredited procedures. The ANSI process assures that interested and affected parties have an opportunity to review, comment, and approve publications as an ANSI standard document via a consensus process.

The IAQ Guideline is intended to be an authoritative source for providing project management guidance in maintaining satisfactory indoor air quality (IAQ) of occupied buildings undergoing renovation or construction. The Guideline covers how to manage the source of air pollutants, control measures, quality control and documentation, communication with occupants. It includes example projects, tables, references, resources, and checklists. The previous edition of the IAQ Guideline is referenced by the U.S. Green Building Council's LEED Green Building Rating System for Existing Buildings and New Construction. SMACNA recommends the guide to architects, engineers, construction managers, facility managers and building owners who will be involved in construction activities inside occupied buildings. Additionally, the principles presented here are also applicable to IAQ problems encountered in occupied areas of buildings during the final phases of new construction.

Methods to identify and remediate lead, asbestos, or other materials that are classified as hazardous materials are not intended to be within the scope of this standard.

SHEET METAL AND AIR CONDITIONING CONTRACTORS'
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CHAPTER 1

INTRODUCTION

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1.1 OVERVIEW

The purpose of this manual is to guide building managers and contractors on controlling construction contaminants so they do not impact building occupants.

Poor indoor air quality (IAQ) is more likely to impact the health of building occupants when construction and renovation projects occur in an occupied building. Dust and odors or other contaminants of concern migrating out of the work area and into occupied spaces can disrupt normal operation of the facility and, under worst case scenarios, cause injury or illness. While IAQ concerns in most buildings are often comfort issues, environmental changes in occupied buildings undergoing construction can have much more serious consequences. The mere presence of detectable dust or odor from a construction project, even at harmless levels, may trigger occupant concerns based on perceived hazards.

Effective management of IAQ during construction requires designers, contractors, facility managers, building engineers, and the occupants to plan and work together. Conflicts regarding scheduling, budget, and continuing facility operation are best resolved early in the design development phase. Waiting for a mid-project air quality “crisis,” either real or perceived, can be costly to all parties. For example, implementing site controls and rescheduling contractors after the project is underway can be highly disruptive.

The expertise of architects, construction managers, heating, ventilation, and airconditioning (HVAC) engineers, and contractors are essential to the solution of most IAQ problems related to construction. Design of interior construction projects should include a detailed assessment of HVAC systems and relative pressurization, including their relationship to the proposed work. Where steps must be taken to protect building occupants from construction emissions, modifying HVAC operation and protecting the HVAC equipment and air conveyance system are often integral parts of the process.

A good construction manager should be trained to recognize activities or conditions which could be detrimental to building occupants. This awareness has become even more critical with the emergence of IAQ-related litigation. While standards for non-occupational air quality are not defined by either OSHA or EPA, specifications in construction contracts or facility leases may address IAQ. In practice, however, IAQ controls are usually based on common sense and good professional judgment. Ongoing documentation of

these decisions made to control IAQ and site conditions may be necessary to demonstrate good faith in regard to potential liability. Even where the best IAQ controls are in place, clear communication between all parties and flexibility to adapt to changing conditions are required for successful resolution of problems.

Construction activities potentially impact occupants both in new buildings where work is ongoing after some areas are occupied and in older facilities which are being repaired, modernized, or reconfigured. This manual will focus on those activities that temporarily produce airborne dust, odor, and other contaminants during demolition, construction, and punch list activities. Longer term IAQ concerns, such as proper design and modification of HVAC systems, are beyond the scope of this manual. The reader is referred to other references published by SMACNA, ASHRAE, and EPA for information on other IAQ issues.

1.2 HOW TO USE THIS MANUAL

No two construction projects are exactly alike. This manual, therefore, emphasizes general concepts and approaches from which the reader can select solutions best suited to a given site (combining these control measures with other construction and facility management requirements depends on an understanding of the entire process).

The remainder of this manual is organized to help answer the following questions:

Chapter

- 2.0 What are the common sources of airborne contaminants during construction?

How do air pollutants move through a building during construction?

How may dust and odors or other contaminants of concern from construction sites impact building occupants?

What are the relative risks of exposure to construction contaminants?

- 3.0 What options are available for protecting IAQ during building construction?

- 4.0 How do the design and operation of HVAC systems affect air quality during construction?



- 5.0 How can a construction project be planned for good IAQ?
- 6.0 Can a pre-construction assessment of the building prevent IAQ problems?
- 7.0 How can work areas be effectively isolated during construction?
- 8.0 How can moisture be controlled during construction?
- 9.0 How can the construction area be monitored for compliance with IAQ requirements?
- 10.0 How should IAQ aspects of a construction project be communicated and coordinated with building occupants?
- 11.0 What troubleshooting measures are recommended for investigating IAQ complaints?

This manual presents generalized options available to help resolve common construction related IAQ problems, and, as such, it is not intended to cover all construction processes and pollutants. It is presented

as a practical overview, not a scientifically detailed treatment of the subject matter. For large or sensitive construction projects in occupied buildings, it is anticipated that design or industrial hygiene professionals will be needed to select from the available control options and adapt them to site-specific circumstances.

TWO FINAL NOTES:

The term “odor” is used in this text to cover any objectionable or potentially harmful gaseous pollutant. Since pollutants from construction activities tend to be detectable in terms of odor at potentially harmful levels, the simplified reference to “dust and odors or other contaminants of concern” is made throughout the text to cover all airborne contaminants. Note that “or other contaminants of concern” is used to remind the reader other contaminants - such as carbon monoxide, PCBs, etc. - may be present without the practical indicators of “odors and dusts”.

This manual does not address worker protection at the construction job site. Compliance with OSHA standards or other applicable requirements on safety, workplace exposure to airborne contaminants, etc., is generally required and must be considered when implementing IAQ controls. Applicable local or international requirements must also be considered.



CHAPTER 2

AIR POLLUTANTS ASSOCIATED WITH CONSTRUCTION

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2.1 SOURCES OF AIRBORNE CONTAMINANTS

Any construction activity which produces dust and odors or other contaminants of concern can be considered a source of air pollutants and a potential contributor to IAQ problems. Airborne contaminants generally originate from construction activities in the following ways:

The disturbance of building materials during repair or demolition creates dust. Particles are typically airborne during initial work, then settle out on surfaces, only to become airborne again during later activity or disturbance (*e.g.*, cleaning). Airborne dust may also be odorous or include microbial contaminants. Materials which may release air pollutants during demolition includes:

- Soils
- Flooring
- Roofing
- Paint
- Masonry
- Ductwork
- Concrete
- Insulation
- Plaster/Drywall
- Ceiling panels
- Fireproofing
- Caulking
- Joint Compound

A second source of air pollutants involves dust and odors or other contaminants of concern originating from products used in the construction process. These include coatings, adhesives, building materials which are applied wet, cleaning agents, etc. Products with potential air quality issues includes:

Building Materials

- Concrete (and treatments)
- Roofing
- Drywall/Joint Compound

- Insulation
- Epoxy flooring
- Wood (including pressed and treated)
- Cove base
- Fireproofing

Wet Products

- Paint (including stains)
- Glazing compound
- Architectural coatings (including sealants)
- Caulking
- Acid finish
- Grouting
- Adhesives
- Sealants

Furnishings

- Carpeting
- Furniture (including natural, pressed, and laminated wood)
- Other flooring
- Partitions
- Wall coverings

Chemical Mixtures

- Solvents
- Fuels
- Cleaning Agents
- Pesticides

Airborne contaminants are also produced by equipment used in the construction process. These may emit combustion products, volatile organic compounds, and dust. Equipment of potential concern includes:

- Generators
- Saw
- Compressors



- Welder
- Forklift
- Troweling machine
- Conveyor
- Pressure washer
- Motor vehicles
- Scrabbler
- Mixer
- Sanders
- Sanding
- Rivet Cutting
- Forklift
- Cutting torch
- Portable heater
- Welder
- Pitch kettle
- Soldering gun
- Other equipment based on combustion such as propane or powder activation

A fourth category of pollutants from construction activity originates from the disruption of building systems. Damage to any system which results in the release of contaminants, such as steam or natural gas, is a potential IAQ concern. Demolition work could eliminate a drain trap, thus allowing sewer gas to enter the building. Another example of system disruption is the release of accumulated dust when ceiling tile or ductwork is disturbed, air volume is increased, or fans are cycled off and on because of renovation, *see* Chapter 4. The stagnant water in potable systems can be another potential hazard in regard to Legionella.

Finally, pollutants can be released from waste materials associated with construction during storage or transportation. Where dust, mold spores, or volatile materials (*e.g.*, rags impregnated with solvent) are intermixed within waste construction materials, the potential for adverse impact on IAQ increases.

Although literally thousands of different chemicals, particles, and microorganisms may be emitted from construction sites, airborne contaminants can generally be placed in one of the following five categories:

2.1.1 Particulates

Demolition of most materials produces only “nuisance dust,” with significant health problems not expected at typical levels of exposure. In most cases, drywall, plaster, concrete, soil, wood, masonry, flooring, roofing, ductwork, pipe, etc., are generally considered to produce only nuisance dust when disturbed, although potentially exposed workers may wear respirators and eye protection as a precaution. Similarly, most dry powders used to prepare insulation, plasters, etc., are considered nuisance dust unless rated as strong irritants. Fiberglass and mineral wool can irritate the skin, eyes, and respiratory tract. Particulates which may be subject to more specific regulation include those containing asbestos, PCBs, and lead and are outside the scope of this guideline. In some situations, labor - saving power tools may generate so much more particulate than “manual” methods that the time and cost of clean ups and containment favors the manual method.

2.1.2 Organic Compounds

Organic compounds are carbon-based chemical products which may release vapors at room temperature and include volatile and semi-volatile organic compounds (VOCs and SVOCs). SVOCs may be present as liquids that can vaporize and recondense on surfaces far from the original source. Their vapors may be detected as odors, depending on concentration and sensitivity of the individual. VOCs are often used as solvents and ingredients in building materials. Odors detected from the following products are considered VOCs: concrete surface treatments, adhesives, paints and architectural coatings, wall coverings, carpeting, vinyl flooring, cove base, roofing compounds, fuels, and spot removers. Most VOCs are considered to be non-toxic or only mildly irritating at typical exposure levels, although ventilation or respiratory precautions may still be advised. Air testing to determine specific chemical concentrations present is usually not considered necessary. Some VOCs may be considered toxic at low levels of exposure, requiring more stringent controls (*e.g.*, benzene).

2.1.3 Combustion Product

Burning of fuels in vehicles, construction equipment, generators, heaters, etc., produces a combination of potentially dangerous gases (*e.g.*, carbon monoxide) and a variety of irritants, including very fine particles. IAQ problems may result when these are not completely vented outside the building. Other sources of combustion products include hot roofing kettles, cutting torches, and fasteners shot with powder activated systems. While the general products of combustion

tend to be similar, emission rates can vary significantly. For example, gasoline and diesel engines pollute much more than those powered by bottled gas, and well tuned engines pollute less than comparable out-of-tune units. While the most toxic product of combustion, carbon monoxide, may be odorless, it is usually present in a mixture with odorous contaminants. Some products of combustion may be considered carcinogens. Combustion sources must always be properly vented.

2.1.4 Biological Materials

Although normal background levels of bacteria and mold are always present in the environment, construction activity may promote conditions favorable to excessive growth or disturb pre-existing biological materials, *see* Chapter 8. For example, wet building materials may need to be either replaced or dried and disinfected before reconstruction. Other examples of biological contamination include bird or rodent droppings or a backup of sewage. In both cases, uncontrolled disturbances of these materials could spread potentially allergenic and infectious dust to occupied building areas or contaminate renovated areas ready to be reoccupied.

2.1.5 Other Contaminants

While most pollutants produced by construction activity are included in Sections 2.1.1 through 2.1.4, other contaminants are sometimes present. These include inorganic (non-carbon-based) chemicals such as ozone from electrical motors, fumes from welding and soldering, and ammonia or chlorine from cleaning compounds.

2.2 HOW CONTAMINANTS MOVE THROUGH BUILDINGS

In most construction projects, little attention is paid to the quality of air at the immediate work site as long as pollutants do not exceed OSHA standards. IAQ concerns, however, may focus on detectable odor or dust outside the work area wherever occupants or the public are located. Identifying potential pollutant pathways is important for maintaining good IAQ, designing a construction project, and locating the source of dust and odors or other contaminants of concern in the event of complaints.

The HVAC system itself is often the primary pathway for building air pollutants. Pollutants can enter the system in at least six ways:

- through supply registers and return grilles.
Note: Pollutants can enter unblocked supply registers and return grilles even when the HVAC fan is not operating
- in ceiling or floor plenums
- through HVAC system intakes located near construction exhaust or outside emissions
- via temporary (construction related) or permanent cross-connections
- into all the above openings via natural or wind-driven air currents when the fan is NOT operating
- through the mechanical room (drawn into the distribution system by the fan)

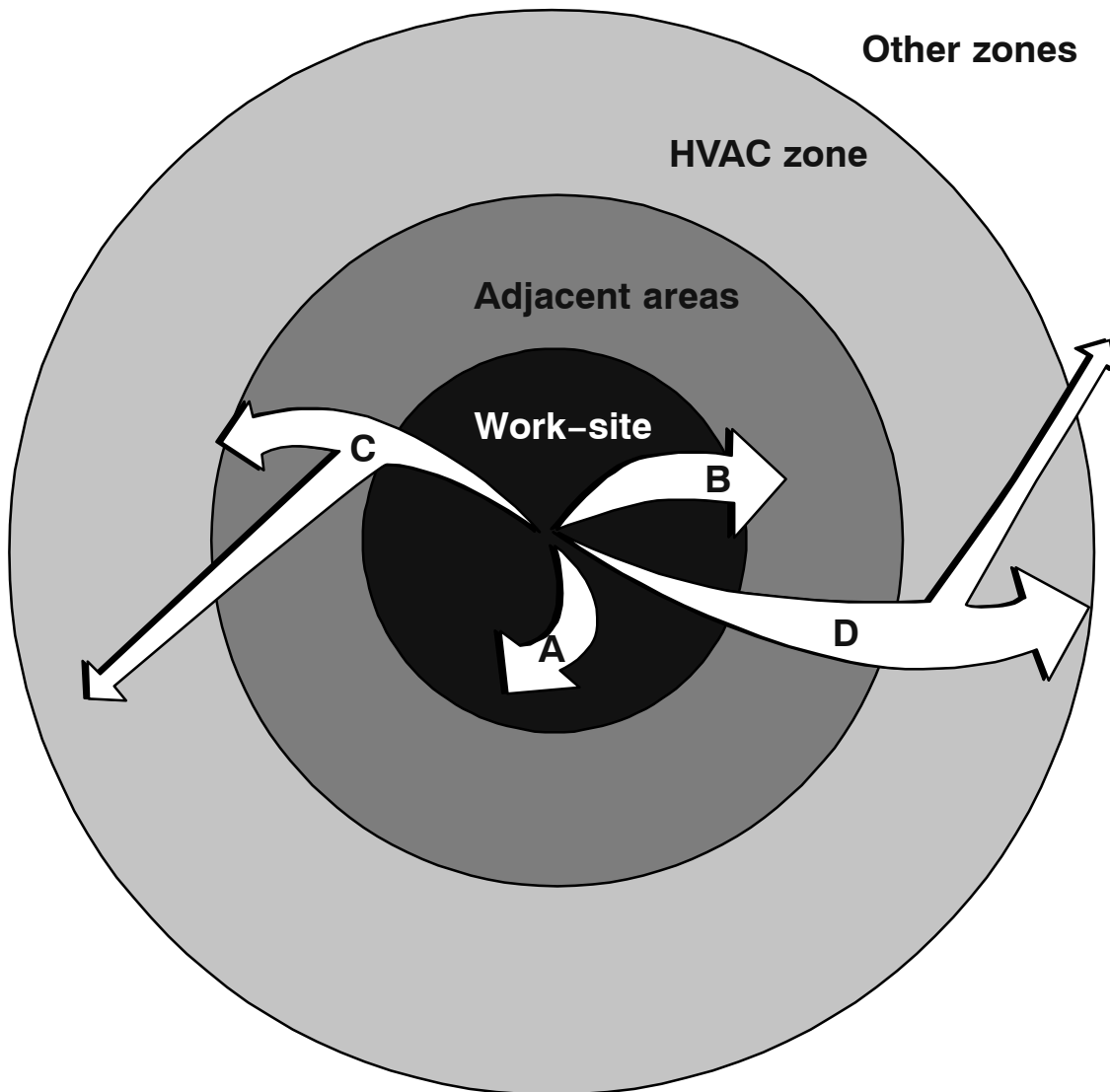
In each case, pollutants will circulate to the rest of the air supply zone and may also contaminate adjacent zones. The extent to which contaminants in the HVAC system are actually considered a problem often depends on how much recirculated pollutants are diluted or filtered, *see* Chapter 4.

Contaminants may be more noticeable when they move directly from the renovation site to locations of lower pressurization. Pollutants tend to migrate from pressurized areas (*e.g.*, more supply air than return/exhaust air) to areas which are under negative pressure (*e.g.*, more return/exhaust air than supply air). Affected locations are generally close-by and on the same floor. However, relative pressurization may move pollutants through the building by the stack effect, to locations on upper floors. Utility chases, abandoned pipes, elevator shafts, stairwells, and similar openings are also pathways which can convey contamination to remote areas of the building under the influence of relative pressurization, *see* Figure 2-1.

The extent to which pollutants will migrate to another area is also related to the size of the opening between the areas and the relative pressure difference between the areas. For example, although some leakage can occur through a small crack, air movement through a larger gap would tend to be greater and through an open door greater still. Demolition work may create new pathways by leaving holes or removing partitions between occupied areas and work locations.

Another potential pathway occurs when dust, solvents, and fibers are tracked outside the work area on workers' shoes and clothing, as well as on contaminated equipment. Once outside the work area, these pollu-





Typical contaminant migration into occupied building areas:

- A. direct exposure of occupants inside work area
- B. tracking of contaminants by workers
- C. movement into areas under negative pressure
- D. recirculation of pollutants drawn into return air system

FIGURE 2-1 COMMON POLLUTANT PATHWAYS FROM CONSTRUCTION SITE

tants can become airborne when they are shed from clothing or equipment. The visual appearance of construction dust in otherwise clean office spaces may raise the level of concern about the impact of construction activity on occupied spaces.

Contaminants may remain detectable after emissions have cleared and accumulate in sites remote from their point of origin. For example, dusts can collect in the ducts, and chemicals can “stick” to porous surfaces such as duct liner. Such sites are considered “sinks” (points of accumulation) which can release these pollutants back into the air at a later time.

Evaluation of air contaminant pathways from construction sites is usually limited to areas within the same building. Occasionally, construction emissions may also impact public areas outside the building or be drawn into the HVAC systems of adjacent facilities. Any such exposure should be of concern and controlled to the extent possible.

2.3 HOW AIRBORNE CONTAMINANTS IMPACT BUILDING OCCUPANTS

Air pollutants associated with construction activity can affect the well-being of building occupants. Whether or not exposures impact occupants is a function of the type of pollutant, the extent to which it accumulates, the duration of exposure, and the sensitivity of the occupants. Of greatest concern are those pollutants likely to cause problems after brief exposure. Examples include solvents that irritate the eyes, nose, and throat; asphyxiants, such as carbon monoxide; and common allergens, such as mold spores. Acute reactions to pollutant exposure are usually nonspecific, symptoms could be due to a variety of other causes in addition to poor air quality. Where symptoms are nonspecific, both a medical diagnosis and a detailed environmental survey may be needed to determine if a person actually became ill because of construction emissions. Hypersensitive individuals may react to common pollutants at levels where most people are unaffected. In cases of true hypersensitivity, it may be impossible to identify specific pollutant sources and it may be advisable to keep hypersensitive individuals (e.g., some asthmatics) as far away from construction activity as possible.

The following case summaries suggest potential problems caused by emissions from construction sites. *Note: These are generalized examples only, not specific diagnoses and are provided as illustrations for when to call in a health professional.*

- An asphalt roofing kettle was located near the HVAC intake. Occupants detected pungent odor and reported irritation of the eyes, nose, and throat, with some also experiencing headaches.
- The demolition phase of a suspended ceiling replacement in an office bay was conducted overnight. Employees returning in the morning observed dusty surfaces. Many were annoyed, and several reported sneezing and itching.
- A gasoline-fired generator was located adjacent to a mechanical room to support construction work. Odors were detected in the zone served by the air handler. Several occupants reported dizziness, nausea, and headaches.
- Adhesive and paint odors were noticeable to employees entering a remodeled office suite. Two contact lens wearers experienced eye irritation.
- While a wall was being replaced, musty odor and mold growth are observed. An occupant of a nearby room subsequently complained of a series of severe asthma attacks.
- Diesel-powered equipment was used in the renovation of an underground garage. Occupants using a connected stairwell occasionally experienced headaches and eye irritation.
- Lead-based paint was stripped from a partially occupied gymnasium. Visitors observed a visible haze in the air and expressed concern about possible lead poisoning.

Since occupant exposure to air pollutants from construction activity tends to be brief, the focus is generally on acute rather than chronic health problems. Cases of chronic diseases, such as cancer, are more likely to be coincidental or pre-existing than construction-related. However, certain demonstrated carcinogens may receive increased attention as a potential liability. It is prudent to keep exposures as low as possible.

To summarize, building-related health problems include by increasing severity:

- Chemical Hypersensitivity: Isolated individuals react to normal background levels of



contaminants-discomfort and mild symptoms

- **Under-Ventilation:** Nonspecific symptoms potentially related to “stuffy” air when no strong emission sources are present-discomfort and mild symptoms
- **Allergy:** Reaction to allergens commonly present in buildings-range from minor congestion to asthma attacks
- **Irritation:** Reactions of the eyes, throat, or skin related to the release of solvents and other irritants-reactions range from mild to severe
- **Legionnaires’ Disease:** Potentially fatal pneumonia-like symptoms’ associated with aerosolized contaminated water affecting individuals with suppressed immune systems-potentially lethal
- **Carbon Monoxide Poisoning:** Occurs when combustion products are not properly ventilated-potentially lethal

While construction activities may be the cause of some health problems, additional occupant complaints may also result from nuisance conditions (*e.g.* excessive noise), discomfort, (*e.g.*, disrupted HVAC operations), or misperceptions, *see* Table 2-1. In such situations, dust and odors or other contaminants of concern may be present, but not in directly harmful amounts. In this setting, occupants may perceive unhealthy conditions, especially where there is a lack of factual information and rumors regarding construction impacts are prevalent. This scenario can be aggravated by poor relations

between building occupants and management or a history of previous problems during past renovations.

2.4 PLACING CONTAMINANT EXPOSURES IN PERSPECTIVE

Air is never pollutant-free, even in the cleanest of buildings. Thus, any air samples should be expected to contain contaminants such as volatile organic compounds (VOCs), particulates (dust), and bioaerosols (bacteria and fungi).

While OSHA standards and other applicable requirements have been set to minimize the possibility of significant illness in healthy adults exposed over a typical work shift, there are no such standards for the general population indirectly exposed to the same contaminants. Building occupants have a wide range of sensitivity with minor, temporary symptoms potentially occurring at levels much lower than the OSHA standards and other applicable requirements. While OSHA standards and other applicable requirements are typically based on exposure to one pollutant at a time, building occupants are generally exposed to a mixture of pollutants. Thus, normal background and harmful levels of airborne contaminants cannot be precisely distinguished. In practice, acceptable IAQ is usually based on conditions achievable with available control measures and is verified by the absence of multiple complaints.

Air sampling is seldom used to regulate building construction projects. Where sampling is conducted, it is often based on general indicators of IAQ (composite measures of particulates, organics, or bioaerosols) rather than identification of all specific pollutant types. Exceptions occur when designated hazards are likely to be present in harmful amounts (*e.g.*, asbestos removal).

Building Environment	Physiological	Psycho-Social
Thermal discomfort (<i>hot/cold; dry/muggy; stuffy/ drafty</i>)	Contagious illness (<i>common respiratory infections, etc.</i>)	Stress (<i>job, personal, etc.</i>)
Physical factors (<i>lighting; noise; ergonomics</i>)	Medication side effects (<i>fatigue, headache, dry mouth, etc.</i>)	Psycho-somatic symptoms
Nuisance conditions (<i>unusual odors; visible dust or staining</i>)	Clustering of random health events (<i>cancer, miscarriage, etc.</i>)	“Sick Building” rumors
Other exposure routes (<i>drinking water; food; skin contact</i>)		

Table 2–1 Other Contributors to Health Complaints Sometimes Attributed to Airborne Contaminants



Air quality assessment of a construction project can be based on:

1. Types of dust, odor or other contaminants of concern produced by:
 - a. materials being demolished;
 - b. products used in construction; and
 - c. equipment used in construction.
2. The presence of any pollutants which are a recognized hazard should be handled with specific precautions as noted on Material Safety Data Sheets (MSDS).
3. A determination of the times and locations occupants are most likely to encounter dust and odor from the project, *see* Section 2.2.
4. The amount and duration of exposure generally expected in these situations.

2.5 HAZARD ASSESSMENT

A hazard assessment need not predict specific concentration values and can simply show the relative

magnitude of environmental problems presented by the various construction phases. An assessment of a typical renovation project could thus be presented as follows:

- Initial removal of asbestos-containing material in the mechanical room and lead-based paint in the lobby could present an exposure hazard unless conducted under full containment.
- Occupied areas adjacent to active work sites may occasionally detect small amounts of nuisance dust and odors or other contaminants of concern (no health effects likely with the possible exception of hypersensitive individuals).
- Odors from enamel painting of executive office doors could be annoying and irritating to nearby occupants for up to two days.

While all three findings suggest that control measures are needed, these can now be prioritized and selected to most efficiently ensure a safe environment for building occupants during each phase of work (*see* the following chapters for more detailed guidance).

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CHAPTER 3

CONTROL MEASURES

3.1 OVERVIEW

A variety of control strategies are available to maintain IAQ during construction or demolition in an occupied building. The pros, cons, and limitations of each available option should be considered when identifying the most effective and efficient approaches for a particular project. In general, the choices involve:

- protecting HVAC systems, *e.g.*, avoid using permanent HVAC systems during demolition;
- controlling the source;
- interrupting pathways;
- intensifying housekeeping; or
- rescheduling work hours.

Projects typically use more than one of these measures, with evolving control strategies as the project phase progresses.

3.2 HVAC PROTECTION

All HVAC equipment must be protected from collecting not only dust but also odors or other contaminants of concern which can “stick” to both porous and non-porous materials in the system and later be released. Use of permanent HVAC equipment in construction areas should be avoided during demolition, *see* Section 4.3. The design of each system must be evaluated in detail to determine how it may be affected by dust and odors or other contaminants of concern from the project including site egress, staging areas, etc. Specific HVAC protection requirements generally apply to either the return side, central filtration, or supply side of the system. Control of building pressurization is another important role played by HVAC during construction (*see* discussion in Chapter 4).

3.3 SOURCE CONTROL

The most effective type of pollution control is generally at the source. A variety of options may be available depending on the type of products and equipment needed for a given construction project. Costs are site-specific. Where more than one control option is feasible, costs can be compared in the selection process.

3.3.1 Product Substitution

In response to IAQ concerns, many manufacturers have been formulating lower emitting products such as:

- carpet
- adhesives
- paints
- caulks
- cleaning solutions
- wall coverings
- furniture

The advantage of low-solvent-emitting products may be only short-term since conventional products may stop significant offgassing within a few weeks. Product emission data is often available from manufacturers and can be stated either as total VOCs or by specific compound. The time frame of any testing, along with cost and performance, is important when evaluating a low-emitting product.

The use of products emitting lower amounts of odor and VOCs may not be critical if the work area is isolated from building occupants and the space will be ventilated for several days before re-occupancy. The advantages of lower emitting products are most evident under the following circumstances:

- Occupants are nearby while product is being applied or installed.
- Odor pathways exist from the work area to occupant space.
- Re-occupancy of the work area must occur very quickly, leaving insufficient time for the materials to offgas.

NOTE: “Bake-outs” of new material are sometimes advocated as a control for offgassing. Heating of furnishings and construction materials is generally not recommended due to questionable effectiveness and potential for damage.

Also, consider cement board instead of paper-covered sheetrock in damp locations or exposed, unpainted applications such as shower rooms and return chases, respectively.



3.3.2 Modifying Equipment Operation

Use of equipment may need to be restricted in order to meet IAQ objectives. This could involve substituting cleaner equipment or simply changing operating procedures. Examples of such controls include:

- restricting traffic volume or prohibiting idling of motor vehicles where emissions could be drawn into occupied areas
- switching from diesel to bottled gas for equipment such as generators or fork lifts, emissions are cleaner but still potentially harmful under some circumstances (use of electric fork lifts and other equipment should be considered when feasible since they do not burn fossil fuels, thus eliminating exposure to combustion gas emissions)
- switching equipment such as saws from gasoline-powered to electric
- adding catalytic converters to engines
- cycling equipment off when not needed

3.3.3 Work Practice Modifications

- For some demolition tasks (*e.g.*, paint stripping), there may be techniques available which produce less airborne dust.
- Some painting techniques release less odor.
- Some cleaning practices raise less dust, *see* Section 3.5.
- Use of hand tools may be cleaner than power tools.
- Vacuum-assisted drywall sanders and concrete saws control dust, *see* 3.3.4.

3.3.4 Local Exhaust

Pollution sources can be directly exhausted to the outside. This may be done through an existing exhaust system, by a portable fan vented to the outside and routed to the work site by flex duct or through a vacuum attachment to a power tool. Depending on the nature of the material and the location of the exhaust, special filtration of the exhaust may or may not be necessary. Any emissions to the outside must be in compliance with applicable outdoor air regulations and

should be directed well away from building fresh air intakes, windows and occupant entry ways. Separation distances from intakes must meet applicable codes and generally should be at least 30 feet.

3.3.5 Air Cleaning

Where exhaust is not feasible, local recirculation of air through a portable air cleaner may be effective. The type of filter should be suitable for the material being controlled (*e.g.*, charcoal or potassium permanganate for many odors, a moderate to high efficiency filter for dust).

3.3.6 Cover or Seal

VOC emissions from evaporation can be reduced by sealing or covering:

- An enclosed tanker is preferable to an open kettle for roofing.
- Containers of wet products should be kept closed as much as possible.
- Waste materials which can release dust and odors or other contaminants of concern should be covered or sealed.
- A surface which is a persistent odor source may be controlled by applying a sealer.
- Solvent-contaminated rags should be kept in closed, flame-proof containers.

3.4 PATHWAY INTERRUPTION

As an alternative to source controls or building evacuation, workplace air can simply be prevented from moving into occupied space. Interruption of potential contaminant pathways can be a very attractive control option. Once major pathways are identified for a given project, the following manipulations may be used to achieve environmental control:

- **Depressurize the work area.** This can be accomplished by adjusting the balance of portable exhaust fans. Construction worker comfort may have to be a secondary consideration where cutting off conditioned air to the work site is needed to help establish a negative pressure environment. Some ventilation of the construction space will still be needed to dilute contaminants and as make-up air to replace exhausted air. This may be provided by

air drawn into the work site from adjoining areas with portable fans.

Air exhausted to achieve negative pressure may or may not need to be filtered, depending on the nature of the materials, location of the exhaust, and any applicable regulations. Care must be taken not to exhaust air where it can be drawn back into the building. In general, at least 30 feet of separation is suggested.

As a general rule, the work site should be exhausted at a rate at least 10% greater than the rate of supply in order to maintain an effective negative pressure.

- **Pressurize occupied space.** Increasing supply air or reducing return/exhaust air in building areas remaining occupied during construction will help exclude airborne dust and odors or other contaminants of concern. While HVAC systems generally shut down at night, consideration should be given to temporarily extending the fan schedule. Overnight pressurization could help prevent dust and odor from migrating into the space. When increasing the amount of air supplied to the occupied space, it is imperative that the HVAC system itself remains protected from construction emissions. Any temporary rebalancing during construction should be carefully planned and executed. When increasing the amount of air supplied to the occupied space, it is imperative that the HVAC system itself remains protected from construction emissions.
- **Erect barriers to contain construction area.** For non-asbestos projects, the extent of the barrier should be based on the materials involved and the implications of dust and odors or other contaminants of concern escaping from the site. In general, full containment of a work site with barriers, capping of return air ducts, and the application of negative pressure may be needed for spaces undergoing significant renovation, but usually not for minor remodeling, *see* additional documentation in Chapter 5.
- **Relocate pollutant sources.** When project equipment or staging areas coincide with critical airflow pathways, IAQ problems can result. In some cases, equipment can simply be moved to a more favorable location in re-

gard to air quality. *For example*, in a roofing job, tar kettles can be located down wind and as far away from intakes as possible, generally at least 30 feet. Also, air intakes can temporarily be redirected with duct extensions. Mechanical equipment might be refurbished outside or in a shop in order to relocate emissions from the building. Special care must be taken to protect mechanical rooms with air handling equipment (*e.g.*, store construction products and waste materials elsewhere).

- **Temporarily seal the building.** Where construction emissions are occurring on the roof or adjacent to a building, contaminants may be drawn in through cracks in the outside air intake if the building is under negative pressure or other entries. If potential contaminant levels are unacceptable and source control, temporary intake relocation, or rescheduling is not feasible, then sealing of intake dampers, windows, doors, or other pathways may be necessary as a last resort. This should be weighed against the creation of stuffy conditions (hopefully of only very short duration) and is likely to conflict with the building code. This adjustment may not be feasible where reduction in pressurization or outside air could create harmful conditions near hazardous materials. Increased infiltration of unconditioned air through building openings could also present problems.

3.5 HOUSEKEEPING

Dust accumulation at a construction site will become airborne when disturbed. Similarly, spills or excess applications of products containing solvents will increase odors at a construction site. Finally, leaving the work site wet for more than a few days could result in the growth of mold. Attention to site cleaning and maintaining dry work areas is, therefore, important to maintaining IAQ during construction. These specific actions may be applicable in regard to controlling contaminants at the work site:

- Suppressing dust with wetting agents or sweeping compounds.
- Increasing the cleaning frequency for dust based on visible inspection, daily cleaning is often necessary.
- Switching to a more efficient dust collection method, such as a damp rag, wet mop, or vacuum equipped with a high efficiency particu-



late filter, wet scrubber, or exterior exhaust, will discharge less material back into the air than conventional vacuuming, sweeping, or dusting. Dry sweeping should not be used but if it is the only feasible alternative a dust-suppression agent should be used.

- Ensuring that all surfaces including higher ledges, behind furniture, and inside mechanical equipment are kept clean. This can be facilitated before the start of renovation by either moving contents out of the work area or covering them.
- Removing spills or excess applications of solvent-containing products as soon as possible. Care should be taken as to selection of spot removers and cleaning agents near occupied areas. In general, products should be low odor emitters or used after hours with sufficient ventilation.
- Vacuuming with HEPA filtered vacuum cleaners prevents aerolization of settled dust.

NOTE: See Chapter 6 for further discussion of moisture issues.

Cleaning requirements are more stringent when hazardous materials are involved. *For example*, the latest edition of the National Institute of Building Standards (NIBS) guidance for stripping lead-based paint includes the following:

1. Clean site daily with proper bagging and disposal of debris.
2. Damp wipe any tools leaving site with detergent solution.
3. Dumpsters should be enclosed or periodically wetted for dust control.
4. When work is completed, HEPA vacuum all affected areas, wash with a detergent solution, and HEPA vacuum again when dry.
5. Repeat until area passes visual inspection and then seal surfaces.
6. Repeat step 3.
7. New building materials or furnishings are not allowed in the area until it passes clearance tests (based on surface wipes).

NOTE: See NIBS guidance related to lead-based paint clean up.

3.6 SCHEDULING

A final control option is to ensure that construction activity and building occupancy do not overlap in time. For many projects, the immediate work area is vacated to prevent safety hazards and work disruption. Although re-occupancy may occur anytime after substantial completion of the work, IAQ concerns may suggest waiting until detectable dust and odors or other contaminants of concern are eliminated. For many major renovation projects, a 48- to 72-hour period of continuous ventilation after final installation and cleaning should typically result in an acceptable environment for re-occupancy. Where possible, the renovation site should be maintained under negative pressure during this period to prevent odor migration into adjacent areas.

NOTE: In mid-summer or -winter the permanent HVAC system is not designed to condition hot humid or frigid air to a comfortable temperature. Longer flush-outs at less than 100 percent outside air or temporary HVAC equipment may be required.

A potentially costly, but sometimes necessary option, is to conduct activities with a high pollution potential during off hours. *For example*, if roofing emissions cannot be excluded from the building, the work might have to be performed on an evening or weekend shift. Similarly, any work which disrupts the HVAC system or introduces odor into the system should be done during unoccupied hours, when possible. Where offgassing odors are a major concern, work may have to be completed at the beginning of a weekend in order to allow new products time to air out sufficiently. Where occupants cannot be relocated, starting time may need to be delayed until late morning in order to accommodate clean-up of late night construction work. Some occupants, such as children or hospital patients, may be particularly vulnerable to construction contaminants. Special considerations for scheduling and occupant relocation may be required.

3.7 OCCUPANT RELOCATION

The above measures assume that occupants are being moved or construction work is being rescheduled in order to avoid potentially harmful exposure to the building's general population. When a construction project is adequately controlled and one or two hypersensitive individuals remain concerned about IAQ, moving those individuals for the duration of the project is often the most economical and effective solution.

For some projects, creating an unoccupied buffer zone around the work area may also be needed to ensure that no odor or dust is detectable in the occupied space. The size of such a buffer zone will depend on the potential air quality problems presented by the project, the availability of temporary space, and the design of HVAC zoning. When necessary control measures are disruptive to conducting normal building activity, it

may be advantageous to vacate the entire floor or building.

When relocating occupants, attention should be paid to environmental conditions in temporary facilities. For example, IAQ in a modular unit could be worse than IAQ at the construction site due to inadequate ventilation and offgassing from new materials.

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CHAPTER 4

HVAC

4.1 HVAC: A CRITICAL FACTOR IN CONSTRUCTION CONTROL

Because HVAC systems are important for maintaining IAQ during and after construction, they require detailed consideration before the construction process begins. Problems may occur when existing HVAC systems also serve construction work areas, differential pressure relationships cause dust and odors or other contaminants of concern to migrate into occupied areas, or HVAC equipment is damaged or contaminated during construction. Return ducts or plenums routed through construction zones may transport construction-generated dust and odors or other contaminants of concern to occupied areas. New ducts and HVAC equipment installed during construction may also become contaminated by sources of dust and odors or other contaminants of concern, if not protected.

Effective management of HVAC systems provides the best answer for preventing or remedying the above problems. The use of temporary HVAC equipment protects existing systems. Early startup of HVAC systems, for example to “bake out” odors or to accelerate concrete drying, can reduce equipment life and operating efficiency where the use of the permanent HVAC system is available in construction areas. In addition, frequent inspection and maintenance of operating systems during the construction period is needed to address the potential degradation from dust, moisture and mold growth, all of which may impact air quality.

When installing HVAC systems, sealants, adhesives, cleaners, paints, solvents, lubricants and other products are used which may impact air quality. Source control or product substitution should be considered where dust and odors or other contaminants of concern present potential problems, *see* Chapter 3. Installation equipment, such as the use of torches, welding, and soldering, often require local exhaust, favorable pressurization, or off-hours scheduling to prevent occupant exposures.

4.2 HVAC PROTECTION

All HVAC equipment must be protected from collecting not only dust, but also odors or other contaminants of concern which can “stick” to porous materials in the system, for subsequent release back into the air. Each system must be evaluated in detail to determine how it may be affected by dust and odors or other contaminants of concern from the project (including site egress, staging areas, etc.) by an engineer experienced in HVAC maintenance and operations.

Options for protecting HVAC equipment include using temporary heating or cooling (often the most effective), sealing openings, disconnecting ducts, filtration, temporary ducts, and controlling pressurization. A review of HVAC systems should be considered before the start of each renovation phase, at a minimum, identifying which systems are within the work area and which of those also serve occupied areas. Specific HVAC protection requirements generally apply to either the return side, central filtration, or supply side of the system.

4.2.1 Return Side

The return side of an HVAC system is under negative pressure and thus capable of drawing in nearby construction dust and odors or other contaminants of concern and distributing them throughout the building. When planning construction projects, special attention must, therefore, be paid to the location of any return vents, return ducts, ceiling plenums, return shafts, VAV plenum intakes, window units, and transfer vents as well as that portion of the air handler which is upstream of the central fan. Containment considerations include:

- When possible, the entire system should be shut down during heavy construction or demolition.
- The system should be isolated from the surrounding environment as much as possible, all tiles should be in place for a ceiling plenum return, and air handler leaks repaired to prevent induction of pollutants.
- All return system openings in, or immediately adjacent to, the construction area should be sealed with 6-mil plastic.
- When the system must remain operational during construction, temporary filters can be added on return air grilles. Suggested minimum efficiency for such filters is 30 percent atmospheric dust spot or a MERV Rating of 6 or higher where feasible. All filters must receive frequent maintenance and be replaced at end of the project.
- Where the permanent HVAC system remains operational, the heaviest work areas can still be dampered off or otherwise blocked if temporary imbalance of the return air system does not create a problem.
- Mechanical rooms with return-side equipment should not be used to store construction or waste materials.



4.2.2 Plenum Protection

Spaces serving as air plenums can also be important pathways for dust and odors or other contaminants of concern generated in construction zones. This can occur during periods of demolition, construction, cleaning or after construction is completed or after air systems are restarted and residual debris is disturbed. In each case, dust and odors or other contaminants of concern can be transmitted through the air distribution system. Therefore, protection of air plenums should be considered in the planning phase of construction. Options include the following:

- Disconnect ducts in the construction zone from the remainder of the active system and seal openings.
- Replace missing ceiling tiles, especially where the ceiling plenum is the return air path.
- Seal openings in new ducts until the construction is finished.
- Consider converting a return air plenum to a ducted system when renovation is scheduled for that area.

Areas with raised access floors (RAF), with or without underfloor air distribution (UFAD) systems, present significant challenges for maintaining IAQ during construction. While modifications to demountable partitions and furniture, electrical systems, communication systems, and computer equipment might not generate much dust and odors or other contaminants of concern; removal or modifications of floor panels could depressurize the plenum, causing comfort problems in other areas. If dust and odors or other contaminants of concern producing operations are conducted, including in adjacent non-RAF areas (restrooms, lobbies, kitchens, laboratories, etc.) RAF and UFAD plenums could easily transport construction generated contaminants or become contaminated themselves. Once contaminated, cleanup of RAF/UFAD plenums could be difficult. Establishing barriers might be difficult because of ducts, piping, cables, and conduit usually located beneath the RAF. Therefore, construction in buildings with RAF/UFAD systems should be carefully planned. Factors for consideration should include the following:

- Consider types of construction and contaminants generated.

- Consider establishing containment barriers at naturally occurring barriers such as smoke barriers. Check that barriers are sealed.
- Determine if the work area HVAC system can be isolated from other areas.
- Prepare for a sprinkler damage event including having equipment readily available for quick water removal, cleanup, and drying.
- Plan how RAF/UFAD will be cleaned if they become contaminated.
- For dust or odorous work, consider scheduling during unoccupied periods with permanent HVAC systems off and sealed as a general construction policy.

4.2.3 Supply Side

HVAC systems in an area where major demolition is scheduled should be de-energized. Equipment left in place should be wrapped (e.g., in 6-mil plastic sheeting). Ducts serving both the occupied and construction areas shall be isolated by sealing openings, closing dampers, or disconnecting the ducts. Direct expansion HVAC systems should be evaluated as to whether reduced airflow will adversely affect direct expansion coil operation. New HVAC equipment can be protected from the weather, dust, and physical damage with appropriate planning and site management. For example, storage of ducts should be located away from masonry or tile cutters, drywall sanding, mortar or plaster mixing, roof pitch kettles, electric generators, and walkways that are frequently broom swept. Duct sections should also be stored in clean, protected areas and shielded from rain to protect against moisture.

Diffusers, VAV boxes, and ducts may be adequately protected in most cases where the above measures are implemented. When the system is off for the duration of construction, diffusers and window units should also be sealed in plastic for further protection. Ducts, diffusers, and window units should be inspected for cleanliness upon completion of the work and vacuumed or wiped where needed. If significant dust deposits remain in the system after construction, some particulate discharge can be expected during start-up. When such a discharge is only minor, delaying reoccupancy long enough to clean up the dust may be sufficient. In more severe cases, installing temporary coarse filters on diffusers or cleaning the ducts may be necessary. The condition of the main filters should be checked whenever visible particulates are discharged from the system.