PROTECTING BUILDING OCCUPANTS DURING CONSTRUCTION AND RENOVATION

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INTRODUCTION

In recent years, there has been increasing emphasis on upgrading existing space through major renovation. With regard to indoor air quality, renovation is the time when occupants are most vulnerable to major contaminant exposure. Despite this, IAQ professionals seldom become involved with non-asbestos aspects of renovation until after severe problems have occurred (Loftness and Hartkopf 1989).

For example, uncontrolled demolition activities caused the evacuation of a portion of a research and development center. Sources of exposure included exhaust from a gasoline-powered saw used to cut concrete and general dust and odor. Investigation showed that the work space was positively pressurized in occupied areas whenever the back exterior door was open and that attempts at protecting the HVAC system (which was left running) had been ineffective.

The purpose of this paper is to examine common IAQ issues that arise in the process of either conducting major renovation or completing construction in occupied buildings. It does not include post-occupancy concerns such as outgassing and ventilation adequacy, the health and safety of construction workers, or asbestos. Instead, the focus is on potential health and nuisance effects on occupants of demolition and construction activities. Approaches (both technical and administrative) to the control of these problems will also be explored.

CONTAMINANTS

Most contaminants generated during renovations are clearly assigned to either the vapor or particulate phase category and behave accordingly. Some, such as tar, overlap into both categories. The toxicology of renovation contaminants varies from low risk to extreme hazard. Representative categories include the following:

1. No known health effects at environmental levels in the general population. Could still be responsible for nuisance concerns and affect the extra-sensitive.
2. Could cause relatively minor, temporary effects at very high concentrations. No lasting effects are likely.
3. Chronic effects are considered likely.
4. Major acute effects are considered likely.

Considerable uncertainty and subjective judgment are involved in assigning potential contaminants to these categories.

PATHWAYS/VARIABILITY

Assuming that direct exposure of construction workers can be maintained within U.S. Occupational Safety and Health Administration (OSHA) standards, the potential effects of contaminants are of real concern only when they can move into occupied or public space. An understanding of such pathways is critical to controlling the IAQ impacts of renovation.

Direct movement of contaminants through the HVAC system can occur in at least three ways.

1. Contaminants enter through return grilles for recirculation into the rest of the air supply zone and any overlapping zones.
2. Contaminants enter the air-handling unit through leaks or openings in central HVAC equipment.
3. Exhausts or outside emissions are drawn into make-up air intakes.

The extent to which contaminants entering the HVAC system will become a problem is building specific. The dilution or filtration of recirculated air may be so great that the contaminants are not detectable.

Contaminants may be more noticeable when they move directly through the building from the renovation site driven by pressure differentials. Affected locations are generally close by and on the same floor, but this can also include movement to adjacent floors and (via stack effect) to remote locations on upper floors.

Direct tracking of dusts, solvents, and fibers from the worksite is another potential pathway. Workers and equipment "shed" contaminants, which can then be tracked into and around occupied space.

Levels of airborne exposure during renovation are typically episodic and can vary by orders of magnitude within short periods of time. Factors affecting such concentrations include

- the scheduling of specific operations,
- the work practices and materials employed,
- other determinants of pressure differentials (wind, etc.),
- temperature and relative humidity, and
- the effectiveness of control measures.

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With the timing and location of peak IAQ exposures changing drastically, measurement of these impacts is often misleading, if not impossible.

TYPICAL PROBLEMS

Roofing

Periodic roof replacement is essential to maintaining the structural and sanitary integrity of buildings. A variety of roofing systems is now available, all of which can present significant IAQ problems during installation.

Fumes generated from holding kettles and freshly treated surfaces during the application of traditional built-up roofs can be a major source of irritation (potential carcinogens are also present). Coal tar pitch fumes heated onsite may be of greatest concern regarding exposure, but asphalt can also generate occupant complaints.

Newer rubber and plastic roofing systems release VOCs during installation, especially during the application of adhesives. Pathways of concern during all types of roof replacement are direct entry into HVAC intakes and the drawing of nearby emissions into negatively pressurized building areas through cracks or openings.

Combustion Products

Operations involving combustion can generate a variety of contaminants, such as carbon monoxide, oxides of nitrogen and sulfur, polynuclear aromatic hydrocarbons, and a range of VOCs. These same operations also produce other pollutants, such as nuisance dusts (during demolition) and ozone or metal fumes (during welding).

Emissions from power equipment depend on the type of fuel (gasoline, diesel, propane, etc.). Equipment of potential concern includes generators and gas-powered saws (e.g., for cutting concrete). The location and timing of equipment use and precautions taken for handling their exhaust will determine if these emissions become an IAQ problem.

Renovation commonly includes various forms of welding, along with brazing, soldering, and cutting with a torch.

Vehicles are sometimes in or under the building during renovation. These can include dump trucks, delivery trucks, passenger vehicles, excavators, and powered wheelbarrows.

For example, employees near the construction of a major addition complained of a variety of nonspecific symptoms. Propane- and diesel-powered equipment was operating within the building with no special provision for exhaust or containment. The work area varied from positive to negative pressure versus the occupied area, depending on the wind direction. Limited monitoring showed CO levels up to 9 ppm and RSP levels up to 150 μ/m^3 in a public corridor. A relationship between the complaints and exposure appeared likely, since they consistently correlated with construction activity and peak levels had not been measured.

Volatile Organic Compounds (VOCs)

Major sources of VOC emissions during renovation include paints, sealants, adhesives, caulks, and furnishings. Peak releases generally occur during application or installation. Other emissions take place from materials that are drying and from leaking products in storage. Products that can have significant short-term effects include lacquers, epoxy paints, adhesives, and curing concrete. Water-based substitutes reduce, but do not eliminate, exposures (Levin 1989).

General Construction and Demolition

While the demolition of building materials generally just creates a nuisance dust, there are at least two major exceptions (in addition to asbestos). Lead-based paint is common in many older buildings. Removal during renovation is the time when significant exposure can occur. Precautions similar to asbestos abatement procedures are needed during removal to minimize rising lead dust levels. Where unsanitary conditions have led to excessive growth of fungi and bacteria, demolition can also create a potential exposure hazard.

The potential hazards when tearing out moldy materials are illustrated by a project at a Maryland elementary school. When the source of allergy problems was traced to mold growth inside the wall cavities of one wing of the school, gypsum board and insulation were scheduled for removal. Because the school was to remain occupied, the following precautions were taken:

- Each work area was sealed in plastic and exhausted to the outside by a nonfiltered window fan.
- A buffer zone was maintained between work areas and school occupants.

During demolition work in each containment, bioaerosol concentrations rose 10 to 100 times over background. A similar increase was measured in the buffer zone when the fan was installed improperly or was shut off prematurely. Any contamination problems were resolved before areas were reoccupied (Light et al. 1989).

Minor Disassembly/Installation While the focus of this paper has been on the potential hazards of renovation, it should be noted that the majority of activities have very little environmental impact. For example, the installation of sheetrock or the disassembly of a suspended ceiling may not release any contaminants into occupied space.

Cleanup At some renovation sites, the greatest amount of airborne dust may be generated during sweeping. Failure to enforce good housekeeping in and around the work area can lead to excessive airborne dust. Cleaning agents are more likely to generate objectionable VOCs during renovations due to the more difficult cleaning problems encountered.

HVAC Disruption of the HVAC systems can impact the comfort and ventilation of building occupants. This might be the result of HVAC changes to accommodate renovation, contamination of the system (e.g., dust that clogs the heating/cooling coils), or accidental malfunctions.

Relocation Moving occupants to temporary quarters during renovation can lead to other environmental concerns. For example, occupants might move to modular units with possible formaldehyde outgassing and inadequate ventilation.

The bottom floor of a building was to be gutted for major rehabilitation while the upper floor, housing a television station, remained occupied. The building owner's concerns were (not necessarily in this order) the health of tenants, protection of the electronic equipment, and bad publicity on the nightly news. An industrial hygiene firm was retained to monitor nuisance dusts on a daily basis. Window exhaust fans were adjusted to maintain acceptable levels.

TECHNICAL CONTROLS

General Goals

1. Contain the work area and/or restrict critical emissions to off hours.
2. Protect the HVAC system from contamination (the return side is most critical).

3. Reduce emissions where needed to prevent contamination of occupied space.

Pathway Elimination

1. Contain and depressurize the work area.
2. Provide a buffer zone around the work area.
3. Attach flex ducts from point sources to the outside (filter as needed).
4. Shut down the HVAC in the work area (construction worker comfort is secondary to IAQ).
5. Protect the return air system.
6. Pressurize the occupied space and extend fan schedule.
7. Relocate emissions (e.g., move tar kettle away from intake).
8. Temporarily seal the outside air intake and/or the roof elevator shaft and roof access door.

Scheduling

1. Change the most offensive activities to evenings and weekends.
2. Delay occupancy until late morning to allow for completion of offensive activities.

Substitution, Reducing Emissions.

1. Reduce solvent content in products.
2. Add a direct capture/filtration system to processes that cannot be exhausted (e.g., HEPA/carbon filter).
3. Use an enclosed tanker versus open kettle for roofing.

Housekeeping

1. Upgrade the efficiency of HVAC filters and change them more often.
2. Suppress dust (wetting, etc.)
3. Change to a more efficient cleaning method (e.g., use HEPA vacuum rather than dry sweeping if microbial or chemical contaminants are present).

MANAGING RENOVATION

Air Quality Criteria

There are no standards applicable to IAQ aspects of renovation projects. When site-specific concerns arise, various guidelines have been used to evaluate measured contaminant levels. Such numerical guidelines have many shortcomings when assessing air quality during renovation. For example, worker protection standards (e.g., OSHA PELs, ACGIH TLVs) do not address nuisance concerns and extra-sensitivity. IAQ guidelines (e.g., 1/10 TLV, WHO) may be more applicable to occupants in general. However, measurement strategies often do not reflect the episodic peaks that characterize the release of contaminants from areas undergoing renovation.

Qualitative performance goals may be a more realistic way to regulate many renovation projects. First, work practices and conditions to control emissions can be specified. These can run the gamut from HVAC modifications to housekeeping. Second, gross indicators of contamination can be used to limit the movements of dusts and vapors. For example, renovation work shall not contribute visible haze, settled dust, or detectable odors to occupied building areas.

Planning

A pro-active renovation program should incorporate an early review of potential emissions from each phase of the project. Each operation should be categorized as to the potential severity of emission and the availability of controls. Where major problems are likely and controls may not be adequate, operations might be scheduled after normal business hours.

Where asbestos or lead-based paint removal is being planned as a first step, the sequence and scope of non-ACM demolition should be carefully considered. When heavy demolition can be accomplished inside a full containment work site, nuisance dusts and emissions from cutting equipment will be controlled better.

A typical team preparing specifications for a major renovation includes individuals with expertise in architecture, engineering, and construction. Air quality aspects may not be adequately considered unless an additional person, trained in the recognition and control of indoor air contaminants, is added to the team. Once the initial project requirements have been proposed, input from an environmental/occupational health scientist, such as an industrial hygienist, might involve

1. identification of hazardous materials such as lead-based paint or pathogenic bioaerosols;
2. identification of critical pathways for contaminant movement into occupied space;
3. control recommendations (ranging from HVAC changes and emission modifications to buffer zones, rescheduling, and housekeeping).

The planning team as a whole should then integrate these concerns into the project, taking into account logistical considerations.

Construction Management

Day-to-day oversight of most renovation is often done by a generalist (construction inspector) or an engineer. Where asbestos is involved, this function may be completely taken over by an industrial hygienist. Other IAQ concerns may also require the involvement of an industrial hygienist but to a lesser extent. Inspection of the air quality aspects of a renovation project might include

1. verification that work practices are being followed,
2. confirmation of pressure differentials,
3. observation of indicators such as dust and odors,
4. response to occupant complaints.

Air quality monitoring may play a role in larger or more sensitive projects. Although routine contaminant measurements may provide documentation and a baseline for the project, they are unlikely to identify or diagnose specific air quality problems. Regular oversight of work practices and inspection for air quality indicators may be more important in this regard.

Enforcement of work practices and air quality criteria should begin with education of contractors or in-house construction crews. Supervisors must be presented up front with a clean, practical, and concise view of the project's IAQ goals and the means for achieving them. On-site inspection, whether by a generalist or an industrial hygienist, must stress consistency and fairness in enforcing work practices. Criteria for warnings and job shutdown should be understood ahead of time. Since many contractors or construction crews may not be familiar with IAQ concerns, field inspectors should take a non-confrontational, cooperative approach when possible.

Communicating with Occupants

Building renovation is a disruptive and often traumatic period for occupants. Fear of environmental exposures may become a major factor, especially when episodic emissions of odor or dust occur in occupied spaces. This can lead to rumors and the spread of hysteria.

Preceding any major renovation project, potentially impacted occupants should be presented with a brief description of the work planned and precautions being taken for air quality protection. Any occupant concern should be discussed at this point and resolved, whenever possible. As demolition and construction progress, periodic updates, including summaries of environmental monitoring, should be presented to occupants.

Despite careful planning and oversight, environmental incidents are sometimes unavoidable. A contingency program, prompt response, and clear communication with occupants are essential at such times. Where exposures have only been in the nuisance category, this should be stated. Any health risks should be presented in perspective. Renovation work should be stopped until potentially significant health issues are resolved.

Case Study The basement of a large shopping mall was being converted to retail stores. Adjacent space remained occupied by a 300-person office. Operations in the work area included large trucks, excavation, demolition, and construction. Air quality considerations were limited to a few small exhaust fans. Soon after work was initiated, many of the office occupants began to complain of headaches, dizziness, irritation, and nausea. Mall management was not responsive until an investigation by the county health department found carbon monoxide levels up to 28 ppm and recommended major modifications to improve air quality. Subsequent improvements included the following:

1. Sealing of mechanical rooms that served as a return plenum and were now drawing in exhausts from several work sites.
2. Substitution of electrical for gas-fired generators and restriction of vehicular traffic in the building.
3. Suppression of dust on roadways and demolition areas.
4. Pressurization of the office with 100% outside air and depressurization of work sites by adding large exhaust fans.

Following these changes, complaints diminished and air quality measurements approached background levels.

IN-HOUSE ADMINISTRATION OF RENOVATION PROGRAM

The Fairfax County Public School (FCPS) System currently is in the middle of a major effort to modernize and expand a number of schools. Air quality has become an important part of this process as much of this work must be done while the buildings are occupied. The program considers IAQ early in the planning process and regularly during on-site inspections. Major goals include keeping dust and odor out of occupied space. Specifications for contractors include:

- use of low-solvent products,
- barriers for dust and fumes,
- dust suppression during demolition,
- daily cleaning of all areas.

Activities producing high levels of emissions are scheduled for after hours or summer. School custodians perform extra cleaning throughout the renovation period. In addition to regular inspections, personnel from the FCPS Risk Management (environmental) office conduct a weekly environmental inspection that includes measurement of dust (with a scattered light detector) and VOCs (with a photoionization detector). Compliance has generally been very good and incidents kept to a minimum.

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