Construction/Renovation Influence On Indoor Air Quality

Airborne particles are generated at construction sites by processes such as demolition, excavation, grinding and sanding. Containment strategies are predicated on the potential impact to construction workers and building occupants.

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Much of the current construction activity in the U.S. is renovation of existing buildings. So IAQ issues related to renovation are becoming more important. Indoor air contaminants that originate from nearby construction projects are also receiving increased attention. In some critical applications such as hospitals, IAQ control protocols have been developed and are being implemented.

Extensive abatement methods for a few activities such as asbestos removal and fire damage cleanup have been developed that provide guidance for more general contamination control efforts.

ASHRAE sponsored a research project to review the published literature and document current practice on indoor air quality issues related to construction and renovation activities (804-RP). This article outlines the major results from the study. A more detailed discussion is given by Kuehn et al.*(Kuehn et al., 1995 and Kuehn et al., 1996).*

Contaminants Caused By Construction

Sources outside the building

Sources of outside air pollution from construction projects range from asphalt roofing fumes to particles generated by excavation. Outdoor sources are varied and often difficult to associate with a specific activity. Dramatic increases of indoor aerosols have been measured during the demolition of nearby buildings. The generation of microbial aerosol from an outside project occurs mainly during excavation when large amounts of dirt movement disrupts the natural habitat of saprophytic fungi.

Contamination from outside sources depends on building openings such as windows, doors and cracks. Other factors include the amount of outdoor ventilation air that enters the building and the level of cleaning applied. Preventing such contamination from the outside seems more readily attainable than recognition and containment of contaminants generated indoors.

Indoor Sources

Generation of Construction Related Indoor Pollution (CRIP) depends on the activities, tools and materials used. The majority of the literature focuses on contaminants that are passively emitted by materials. Very little information exists regarding sources of airborne contaminants from active construction processes.

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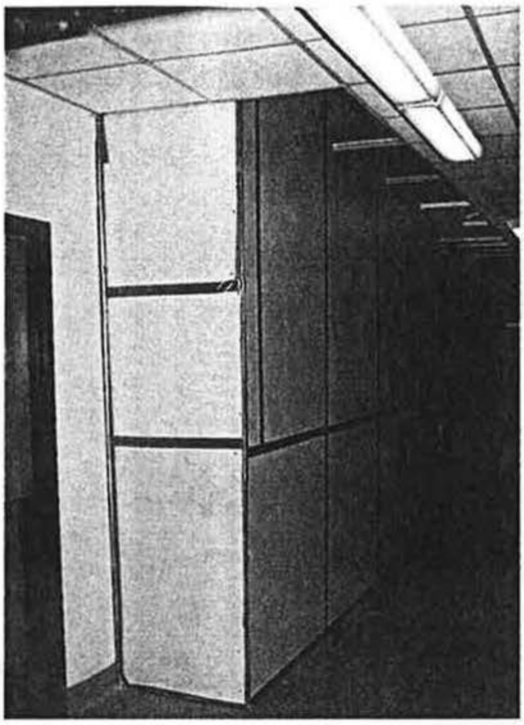
Gases and Vapors: When gases or vapors are generated, the rate of chemical emission is proportional to the vapor pressure of the substance, the amount of vaporizable material, surface area, diffusivity through materials and local environmental conditions. Even low volatile substances such as latex paints can produce vapors which cause significant occupant complaints.

Emissions from new furniture have been implicated as a significant source of VOCs in new construction by Dols, Persily and Nabinger *(Dols, Persily, and Nabinger, 1992)*. Emissions from new building materials were associated with sick building syndrome by Nielsen *(Nielsen, 1988)* and Chang *(Chang, et al., 1994)*. New office buildings have been frequently studied *(Dols, Persily, and Nabinger, 1992, Grot et al., 1991)* to determine what aspects of the project increase VOCs.



Generation of construction-related indoor pollution depends on the activities, tools and materials used. Emissions from new furniture have been implicated as a significant source of VOCs in new construction.

Tucker *(Tucker, 1988)* and Tichenor and Guo *(Tichenor and Guo, 1988)* report experimental data on the emission rates of various materials. These data are useful for determining the type of conditioning a building material should be given to reduce VOC emissions when the building is occupied. Tucker indicated that materials with rapid decay rates such as floor adhesive and floor wax, although they have very high initial emission rates, tend to offgas rapidly so they are not a significant factor in the building occupant exposure.

He argued that these "rapid-decay materials" do not need to be conditioned or reformulated. However materials with much longer decay time constants and similar high initial emission rates should be conditioned so the long term emissions in the structure will be lowered when the building is occupied. Some of the experiments by Tucker used elevated temperatures and high ventilation rates to determine their effect on building materials. These investigations have shown that increases in ventilation rate enhances the offgassing of materials.

Varying the humidity will also effect the emissions, especially if the material is considered to be a "wet" application material. High relative humidity increases the emission rates in some materials (wood based products, ceiling tile) whereas reduced humidity increases the emissions in others (gypsum board, cement block). The type of "in situ" conditioning would depend on the occupancy status of the building, the capacity of the ventilation system and the ability to control temperature and humidity.

Offermann et al. *(Offermann et al., 1993)* tried to determine whether "bakeout" would be useful as a means of decreasing exposure during initial occupancy. The success of this technique varied. Some short term benefits were achieved. However, many gaseous contaminant concentrations tended to rebound to those present before the bakeout. This is probably caused by the long time constants associated with many of the materials used in the building.

Non-Organic Particles: Airborne particles are generated by a variety of processes (i.e., demolition, excavation, grinding, drilling, cutting, sanding, disturbing settled dust, etc.) at the construction site. During demolition, a variety of dust aerosols related to the removal of old material are generated.

The disruption of asbestos is a particular hazard which is closely regulated in the U.S. and is not recognized as a significant IAQ problem. Efforts to manage asbestos dust from debris include airflow direction and construction worker traffic control through occupied areas. Barrier protection and disposal control are a part of the regulation of this hazardous material.

While regulation mandates careful control of asbestos aerosol, control of other construction particle aerosols is not as well developed. The effects of particles from wood, cement, gypsum, shaved plastic, insulation fibers and mineral ceiling fibers have been studied. Aerosol particles from old paint may also be hazardous because lead based paints were often used in older buildings.

Flame cutting, grinding and surface removal generate copious amounts of dust. The local worker is most often protected with a respirator. However, residual dust settles if not removed. Subsequent disturbance and aerosolization of that dust may then allow it to be inhaled when workers are not masked.

Viable Particles: Indoor viable particle aerosols are mainly generated during the demolition of areas that have experienced high moisture levels and prior fungal growth. Demolition will inevitably disrupt loci of fungal growth or accumulations of spores and release them along with other particles.

Recognition of these sources is extremely difficult except by trained personnel. This issue is especially important for hospitals caring for cancer or transplant patients receiving immune suppressive therapy where fungi of the species *Aspergillus fumigatus* or *A. flavus* can cause respiratory fungal infections. Construction workers will most often protect themselves with a respirator to reduce their exposure.

The obvious solution to prevent other workers and building occupants from inhalation exposure is to provide barrier protection near the source and airflow direction control through air pressure control.

Health Effects of Construction/ Renovation Pollutants

The health effects of pollutants generated during construction and renovation activities can be separated into several groups. The construction process itself is a heavy industrial process. Workers in the industry can be exposed to high levels of pollutants unless reasonable precautions are taken at the building site.

If these pollutants are able to penetrate adjacent, occupied buildings or occupied areas of the same building, adverse effects among the occupants can be seen. Finally, after the building construction is completed the new materials and finishes represent unusual pollutant sources causing health effects within buildings.

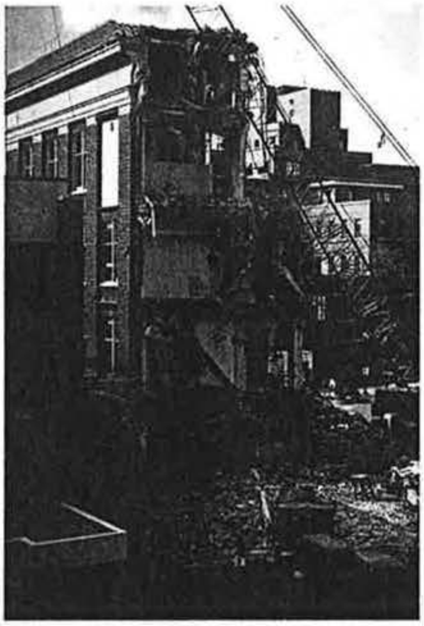
Construction Worker Exposures

Effects of construction and renovation on human health begins first with the construction workers and their exposures. The affect on construction workers may differ from that on building occupants for a variety of reasons. Construction workers often have natural ventilation due to the reduced confinement of the construction zone. Also construction workers are aware of the contaminant generation and have some control over their own exposure, whereas a building occupant may not.

Health effects from the high-level exposures of a short duration may provide guidance that directs investigators to examine appropriate health end points for long-term low-level exposures. A comparison of construction hazards is presented by Fairfax *(Fairfax, 1994)*. He notes that based on complaints over a four year period to the Occupational Safety and Health Administration (OSHA), construction workers are exposed most often to lead (structural steel work), asbestos, noise, and silica dust (tunneling and concrete construction).

Exposure to lead occurs in several ways. Spee and Zwennis *(Spee and Zwennis, 1987)* report field measurements that track lead exposure and uptake in workers demolishing a steel structure using flame-torch cutting. The results show that without the use of effective respiratory protection, severe lead poisoning would occur. Further documentation comes from the California Occupational Lead Registry *(Waller, Osorio et al., 1992)* covering the period from April 1987 through March 1989.

Although construction workers made up only 1% of the registry, 18% of the workers with high blood levels (above 80 μg/dL) were from this industry. Investigation of the results indicated that exposure to paint was the likely source of the lead. Workers affected reported symptoms of fatigue and difficulty concentrating. Additional work has been published on exposures to silica dust, asphalt fumes, paint and formaldehyde.



Construction activities which generate large amounts of dust should be scheduled when buildings are unoccupied so outside air intakes can be closed.

Exposures to Non-construction Personnel

The materials and processes that construction workers are exposed to may penetrate adjacent buildings or occupied areas of the same building and present their occupants with lower, but still meaningful, exposures. Health effects of air pollutants can be observed with relative ease in healthy individuals when there are exposures to high concentrations. As noted above, such exposures can occur on the job site during construction. The effects on individuals in adjacent occupied areas are less well understood.

Most often the concentrations observed in adjacent buildings are lower. In these cases the health effects are more difficult to measure. There is an important exception to this that is well-documented in the literature. Individuals in adjacent buildings who are sensitive to certain substances can have serious health effects even at very small exposures. Patients in health care facilities whose immune systems function poorly because of disease or medication are particularly vulnerable to airborne viable particle contaminants. Two representative documented cases are described here.

Case 1: Sarubbi et al. *(Sarubbi et al., 1982)* report an increase in *A. flavus* in respiratory tract specimens in a group of patients located in an old wing of the NC Memorial Hospital. Investigation showed that this wing was located adjacent to new hospital construction. Air sampling in these rooms showed a significant fraction of rooms with *A. flavus* . Sampling in rooms in other portions of the hospital showed smaller airborne concentrations. The authors conclude that invasive aspergillosis is caused by unfiltered air entering the patient rooms from new construction.

Case 2: Streifel *(Streifel, 1988)* examines the relationship between aspergillosis and construction. The paper reviews evidence of an association between outbreaks observed and existence of construction/renovation activities in the hospital. The paper includes an extensive discussion of sampling procedures and control recommendations.

Several observations should be noted about these reports. The authors report an increase in invasive aspergillosis associated with renovation or nearby construction. The studies are rigorous examinations of the relationship between aspergillosis and the presence of construction. Even though the health outcome has been severe (mortality) and advice has been available to building managers, cases continue to occur. Either the recommendations are being ignored or the control recommendations are inadequate to reduce the problem.

The severity of the health effects makes this an issue that must be resolved. It is reasonable to assume that similar construction related exposures

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Extremely Helpful	*450*
Helpful	*451*
Somewhat Helpful	*452*
Not Helpful	*453*

biological contaminants. The level of concern will influence the potential activities/sources and the susceptibility of the workers/building occupants to the contaminants generated. Cost of implementation should be balanced with potential benefits of health and productivity.

One of the major requirements of a successful project is adequate planning prior to the construction phase and continuous communication between the architect, engineer, contractor and owner. Many problems that have been documented could have been avoided or the impact greatly reduced if there had been adequate communication and mutual understanding of the consequences of the various activities associated with the construction.

The following recommendations are listed as a general guide to be followed for any construction/renovation project. The scope of an individual project will determine what control measures are adopted.

I. *Planning and Communication*

A protocol must be developed at the beginning of the project to identify the representatives from the architect, general contractor, and building owner to address the issue of construction related airborne contaminant control and the potential effects on construction workers and building occupants. Others, such as the engineers and subcontractors, should be involved where necessary.

A construction impact statement should be developed that outlines the expected activities/sources and the susceptible workers/occupants. A risk assessment should be made. A budget should be developed for the necessary control methods to be employed.

II. *Develop Control Techniques in Specifications*

Bid document specifications should be developed. The type, amount and timing of the various control measures should be written in the job specifications. They will depend on the particular project. However a set of general control measures that should be adopted in all building construction projects, depending on whether the material is for outside or inside sources.

<u>Outside sources:</u>

- Minimize building penetrations and control those that are necessary;
- Site construction related equipment away from building access areas when possible and away from air intakes;
- Route traffic away from building openings when possible;
- Modify air intakes by adequate filtration and/or relocating; and,
- Schedule exterior construction activities that generate large amounts of dust during unoccupied hours when possible so outside air intake can be turned off.

<u>Inside sources</u> (these usually dictate the level of control necessary)

- Vacate the space being renovated for small jobs;
- Schedule the activities with respect to the occupancy schedule whenever possible;
- Specify materials and supplies with minimal contaminant generation;
- Install barriers between work areas and occupied areas;
- Provide negative pressure in work areas and filter any air discharged outside or if necessary into occupied areas with HEPA filters for particle removal;
- Schedule utility outages for minimum amount of time and impact on occupants; and,
- Route material deliveries and refuse removal through outside penetrations into the work area, not through occupied space.

III. *Bid Documents*

- Contractor designates representative for IAQ issues;
- Channels of communication with subcontractors established;
- Contractor must adequately respond to the required IAQ control measures called for in the specifications and provide the necessary means to cover the costs; and,
- Specify conditions that would warrant emergency response.

IV. *Implementation*

- Ensure contractor's IAQ officer is trained and has the authority to correct problems that arise;
- Hold regularly scheduled meetings between the general contractor, subcontractors, architect, owner and engineers to solve problems related to IAQ issues; and,
- Test and monitor ventilation and exhaust airflow and suspected contaminant particles and gases within occupied areas of the building.

V. *Commissioning*

- Include IAQ monitoring in the commissioning process;
- Sample to determine concentrations of suspected airborne contaminants that may include gases, non organic particles and viable particles;
- Use 100% outdoor air before and during initial occupancy
- Ensure correct air handling system balance; and.
- Do not accept ventilation deficiencies as a deductible in the contract.

VI. *Warranty*

- Owner should be protected against long term effects caused by construction materials and workmanship (for example water damage during construction may result in mold growth and subsequent material decay and potential occupant health impacts).

Conclusions

This review of the published literature indicates that a significant body of knowledge exists concerning impacts of construction or renovation on indoor air quality. Medical facilities, primarily hospitals, have received the most attention due to the highly susceptible patient population. Guidelines have been developed for hospitals that can readily be adopted for other building types.

However there is scant information regarding the cost or effectiveness of the various recommended control options. Work should be undertaken to better quantify these with the understanding that human factors such as training and communication can play a major role in the effectiveness of any control option adopted.

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