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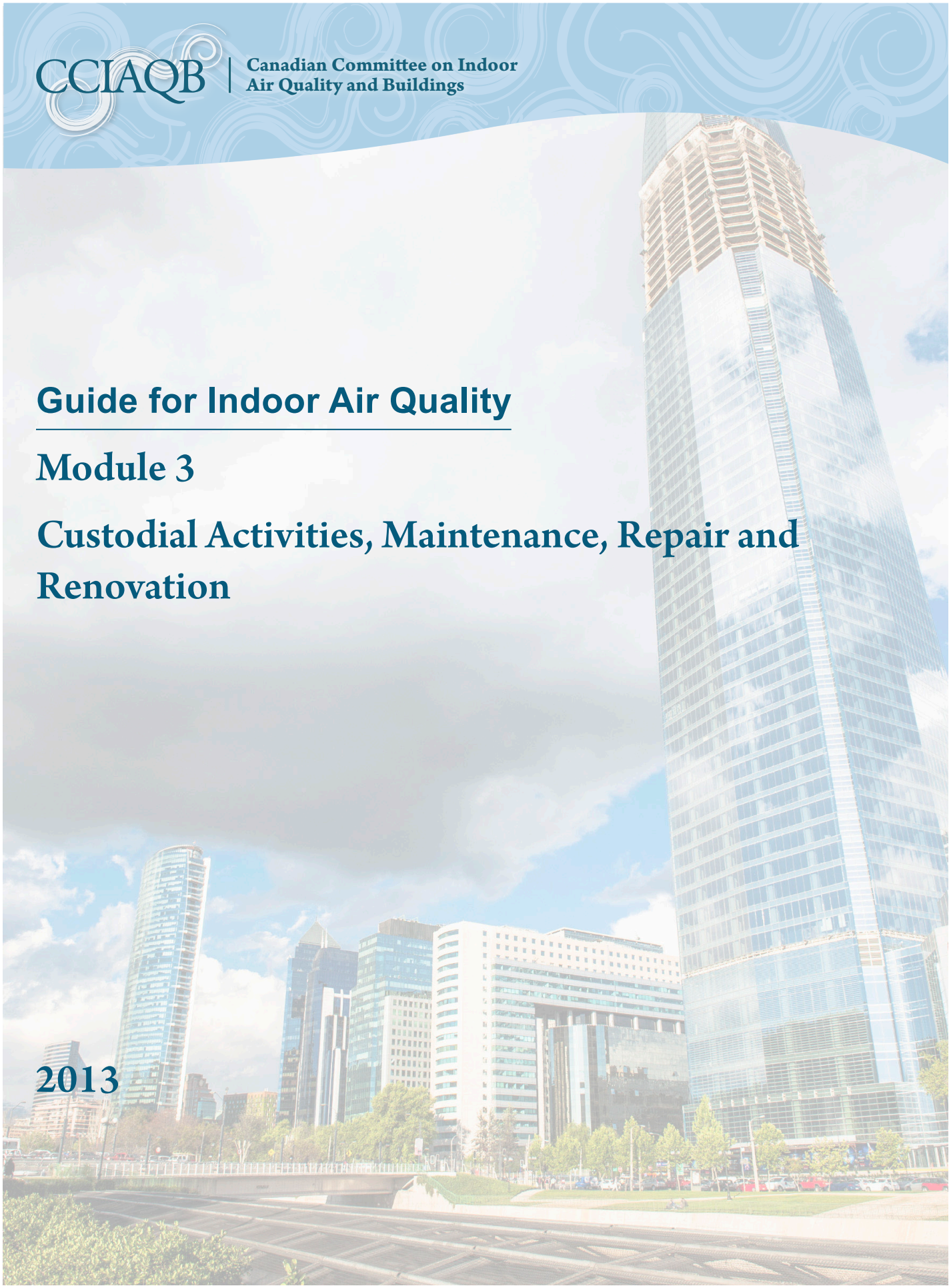

Guide for Indoor Air Quality

Module 3

Custodial Activities, Maintenance, Repair and Renovation

2013

Canadian Committee on Indoor Air Quality and Buildings (CCIAQB)

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Indoor air quality is a very complex issue and there is currently a significant gap between knowledge of the effects of indoor air quality on the health of occupants and the effectiveness of various air quality technologies and solutions. User discretion is advised.

Preamble

The objective of the CCIAQB is, ultimately, to improve indoor air quality for all Canadians in every type of building. The CCIAQB has decided that its initial focus should be on buildings where many Canadians spend time outside their home, working, learning, shopping, being entertained, etc. For the most part, these buildings have relatively complex heating, ventilating and air conditioning systems that are operated and managed by knowledgeable persons. The table below gives examples of buildings that are covered using the classification found in the National Building Code of Canada (NBC). Documents produced by the CCIAQB are primarily intended for the use of building operators and facility managers, but the information contained in the guides can be helpful to anyone seeking a general understanding of indoor air quality issues.

The Committee welcomes feedback on the documents as well as ideas for the development of new materials. Contact the CCIAQB Secretary at info@IAQforum.ca or register on the website at www.IAQ-forum.ca

NBC Classification	**Examples**
Group A, Division 1	Theatres, movie theatres and other facilities for the performing arts
Group A, Division 2	Art galleries, museums, libraries, educational facilities (schools, colleges and universities), gymnasia, air and rail terminals
Group A, Division 3	Arenas and swimming pools
Group C	Apartments, hotels, college residences
Group D	Offices, including medical and dental offices
Group E	Department stores, supermarkets, shops, retail space

Guide for Indoor Air Quality
Module 3: Custodial Activities, Maintenance, Repair and Renovation

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1. Purpose of This Module

Many indoor air problems can be prevented by following sound maintenance and housekeeping practices such as: maintaining good sanitation, providing adequate ventilation, and using suitable cleaning agents. The purpose of this module is to help managers maintain buildings in a way that contributes to acceptable indoor air quality.

This document is part of a series of modules forming the *CCIAQB Guide for Indoor Air Quality* available at www.IAQForum.ca. For acronyms and definitions, refer to *Module 1 – Introduction to Indoor Air Quality (IAQ)*.

2. Importance of Indoor Air Quality

A healthy indoor environment contributes to occupant productivity, comfort, health and sense of well-being. Failure to consistently provide acceptable air quality could:

- Increase health problems such as coughing, eye irritation, headache, and allergic reactions, and, in rare cases, more serious health problems (e.g., Legionnaire's disease, carbon monoxide poisoning);
- Contribute to absenteeism and loss of productivity;
- Strain relations between landlords and tenants, and employers and employees;
- Create negative publicity that could threaten leasing opportunities or bring liability problems; and
- Accelerate deterioration of furnishings and equipment.

3. Sources of Indoor Air Contaminants

Indoor air contaminants can originate within a building or be imported from outdoors. If contaminant sources are not controlled, IAQ problems can arise, even if the heating, ventilating and air-conditioning (HVAC) system is properly designed and well-maintained. Some sources of air contamination are shown in Table 3-1.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has developed strategies and objectives for overall indoor air quality. The ASHRAE objectives that can be influenced by custodial activities, maintenance and renovation are:

- Control moisture in building assemblies;
- Limit entry of outdoor contaminants;
- Control moisture and contaminants related to mechanical systems;
- Limit contaminants from indoor sources;
- Capture and exhaust contaminants from building equipment and activities; and
- Reduce contaminant concentrations through ventilation, filtration, and air cleaning.

4. Custodial Activities

A clean indoor environment is generally considered an essential requisite for acceptable indoor air quality. If chosen poorly, cleaning agents and/or practices can have detrimental effects on indoor air.

Buildings designed to minimize the need for cleaning and facilitate cleaning with non-toxic and noncorrosive agents, and that have documentation identifying proper cleaning methods are more likely to have a clean and healthy indoor environment.

Operating a building to maintain acceptable air quality is a complex process that can be made routine by implementing good building stewardship. Checklist 3-1 (page 3) provides suggestions for developing an IAQ management plan.

Table 3-1 Typical sources of air contaminnation in buildings

1. **Contaminated outdoor air**
   - 1.1 Pollen, dust, fungal spores
   - 1.2 Industrial pollutants
   - 1.3 Exhaust from vehicles on nearby roads, parking lots, garages, or loading docks
   - 1.4 Odors from dumpsters
   - 1.5 Importation of exhaust from the building itself or from neighbouring buildings
   - 1.6 Unsanitary debris near air intakes
   - 1.7 Pesticides
2. **Soil gas**
   - 2.1 Radon
   - 2.2 Leakage from underground fuel tanks
   - 2.3 Contaminants from previous site uses (e.g., landfills)
3. **HVAC system**
   - 3.1 Dust or dirt in ductwork or other components
   - 3.2 Microbiological growth in drip pans, humidifiers, ductwork, coils
   - 3.3 Improper use of biocides, sealants, and/or cleaning compounds
   - 3.4 Improper venting of combustion products
   - 3.5 Refrigerant
   - 3.6 Building air flows and gradients causing cross-zone air movement
4. **Non-HVAC equipment**
   - 4.1 Emissions from office equipment (volatile organic compounds, ozone)
   - 4.2 Supplies (solvents, toners, ammonia)
   - 4.3 Emissions from shops, labs, cleaning processes
   - 4.4 Elevator motors and other mechanical systems
5. **Personal activities**
   - 5.1 Smoking
   - 5.2 Cooking
   - 5.3 Portable devices (e.g., humidifiers and air cleaners)
   - 5.4 Body odor
   - 5.5 Personal care products
6. **Housekeeping activities**
   - 6.1 Cleaning materials and procedures
   - 6.2 Emissions from stored supplies or trash
   - 6.3 Use of deodorizers and fragrances
   - 6.4 Airborne dust or dirt (e.g., circulated by sweeping and vacuuming)
7. **Moisture or standing water**
   - 7.1 Rooftops after rainfall
   - 7.2 Crawlspaces
   - 7.3 In-ground duct systems
8. **Maintenance activities**
   - 8.1 Microorganisms in mist from improperly maintained cooling towers
   - 8.2 Airborne dust or dirt
   - 8.3 Volatile organic compounds from use of paint, caulk, adhesives, and other products
   - 8.4 Pesticides from pest control activities
   - 8.5 Emissions from stored supplies
9. **Building components and furnishings**
   - 9.1 Textured surfaces such as carpeting, curtains, and other textiles
   - 9.2 Chemicals released from building components or furnishings
   - 9.3 Clutter
   - 9.4 Open shelving
   - 9.5 Old or deteriorated furnishings
   - 9.6 Materials containing damaged asbestos
10. **Unsanitary conditions and water damage**
    - 10.1 Microbiological growth on furnishings or building components
    - 10.2 Standing water from clogged or poorly designed drains
    - 10.3 Dry traps that allow the passage of sewer gas
11. **Accidental events**
    - 11.1 Spills of water, food or other materials
    - 11.2 Microbiological growth due to flooding or to leaks from roofs, piping
    - 11.3 Fire damage (soot, PCBs from electrical equipment, odors)
12. **Special use areas**
    - 12.1 Smoking lounges
    - 12.2 Laboratories
    - 12.3 Print shops, art rooms
    - 12.4 Exercise rooms
    - 12.5 Beauty salons
    - 12.6 Food preparation areas
13. **Redecorating/remodeling/repair activities**
    - 13.1 Emissions from new furnishings
    - 13.2 Dust and fibers from demolition
    - 13.3 Odors and volatile organic and inorganic compounds from paint, caulk, adhesives
    - 13.4 Microbiologicals released from demolition or remodeling activities

Adapted from *Building Air Quality: A Guide for Building Owners and Facility Managers, EPA (1996)*

Checklist 3-1 Elements of an indoor air quality management plan

1. Have and maintain a building IAQ profile (See Module 1, Introduction to Indoor Air Quality and Module 8, Creating a Building IAQ Profile).
2. Develop and maintain close communications with tenants/occupants.
3. Educate custodians, tenants and occupants about air quality and practices.
4. Clean to protect health and the environment first, and in most cases, the appearance will be addressed at the same time (even clean appearing buildings can be unhealthy).
5. Clean and maintain the building as a whole, not just as separate components (cleaning and maintenance in one area of a building can have a major impact on other areas).
6. Schedule routine cleaning (see Cleaning Procedures) that is frequent and thorough.
7. Establish plans to deal with accidents such as spills, water leaks, smoke or air contamination.
8. Minimize human exposure to harmful contaminants and cleaning residues.
9. Ensure workers always use appropriate personal protective equipment.
10. Provide areas where work is taking place with adequate ventilation
11. Establish work schedules to minimize exposure to building occupants
12. Use the most the benign products to accomplish the task (see Cleaning Products).
13. Minimize chemical, particle and moisture residue when cleaning. The products that are used for building maintenance due to their ability to quickly and efficiently remove oils, soils, living organisms, etc., can also contribute to a building's problem if used incorrectly.
14. Minimize the amount of pollutants entering the building, while maximizing the amount of pollutants extracted.
15. Dispose of cleaning waste in conformance with manufacturers' recommendations and local requirements.

4.1. Cleaning Procedures

While cleaning can reduce exposure to contaminants, it can also cause pollutants such as mould spores, dust, chemical emissions and other harmful contaminants to be released into the air. This section describes cleaning procedures intended to minimize the negative effects of cleaning.

Protocols for effective cleaning need to be included in operation and maintenance (O&M) documentation and training. These should include: the equipment employed in cleaning operations; the timing of cleaning activities; the provision of adequate building ventilation during and immediately following cleaning operations; and the training of cleaning personnel in all these issues.

Where custodial services are done under contract, the terms should specify the desired cleaning procedures.

4.2. Dusting and Dust Mopping

Dusting may move dust and other contaminants from one area to another, such as from a bookshelf to the floor, or make settled dust become airborne. Dusting should be done in a way that captures dust rather than reintroducing it to the air where it can be inhaled. For best results:

- Ensure that dust mops are properly treated to capture dust;
- Use wide-area vacuums fitted with appropriate bags/filters
- Use lint-free dusting cloths or a vacuum instead of feather dusters.

It should be noted that regular vacuums with ordinary bags/filters are not capable of retaining fine particulate matter, including mould spores and fragments, causing an effective reintroduction of the materials collected from the floors and other surfaces back into the indoor air. Consider the use of vacuums equipped with HEPA filters.

4.2.1. Entryways

Entryways are the first line of defence against the importation of water and snow, de-icing chemicals and abrasives and other undesirable elements into a building. During and after snowfalls, keep outside walkways clean to minimize the quantity of snow and slush coming through the doors.

Use mats of sufficient length inside entryways so that, as an adult walks across the mat, each foot hits the mat at least twice (a minimum of 3 to 4 m). To be effective, mats need to be cleaned and dried so that debris is not tracked past the entryways.

Keeping building entrances clean in winter can be a challenge

4.2.2. Floor Care (uncarpeted areas)

Floor care begins by employing strategies to minimize the need for floor stripping and waxing. Those may include:

- Considering the short and long term maintenance requirements in addition to first cost when selecting flooring;
- Keeping outside entryways clean to prevent soils from being tracked into a building;
- Using entry mats effectively to capture soils;
- Frequently cleaning entryway mats and grates; and
- Frequently cleaning floors close to entryways and sources of particulates such as near printers and photocopiers.

When floors need to be spot cleaned, solutions should be applied from a sprayer in a stream (not as a fine mist) or dabbed on to minimize the amount of material that is atomized and potentially inhaled by occupants. See Section 5, Cleaning Products, for floor maintenance products that minimize emissions.

When floors need to be stripped, recoated or extraction-cleaned, it is important that occupants be notified well in advance. It is preferable to conduct major cleaning activities on a weekend or during some other extended time period when occupants will not be in the building. This allows maximum time for the building to be ventilated with fresh air and the use of dehumidification equipment prior to the return of the occupants.

It is preferable to use the least-toxic products possible (see Section 5 *Cleaning Products*) and to use as little water as possible. Select appropriate pads for the equipment and floor finish. When using high-speed burnishers, it is important to use vacuum attachments to minimize particles in the air.

To maximize the longevity of a floor, make sure there is a solid foundation of finish on the floor. Dry buffing and burnishing acts like sandpaper on wood and increases the appearance by removing layer after layer to smooth out the surface - the smoother the surface, the shiner the appearance. However, if too much floor finish is removed, then dry buffing and burnishing can actually damage floor tile and increase particle emissions into the air. Dry-buffing of vinyl asbestos tiles requires careful consideration since it could introduce asbestos fibres into the air.

4.2.3. Carpet Care

The strategy for minimizing the effect of carpet care on air quality begins with maintaining a high level of cleanliness at building entrances. Vacuum cleaning should:

- Use equipment in good working order fitted with appropriate bags and/or filters (consider the use of HEPA filters).
- Vacuum bags should be emptied or replaced as required to maintain adequate suction.

Carpets can store undesirable dirt and microbials that can be activated when moisture is added, such as when extraction-cleaning is used. Effective cleaning and minimization of emissions can be achieved by:

- Notifying occupants prior to large-scale extraction-cleaning activities and scheduling them for periods when a building is to be unoccupied such as before weekends and holidays. As more and more tenants are working during off-office hours, communication is important to determine times that are mutually acceptable.
- Selecting appropriate cleaning solutions (see Section 5, Cleaning Products).
- Minimizing the amount of cleaning solution used.
- Using appropriate functioning equipment that will maximize the amount of water being extracted from the carpet to minimize moisture and potential for mould, mildew and bacterial growth. Only in special situations should disinfectant be used after extraction-cleaning to prevent mould, mildew, and bacteria growth.
- Increasing ventilation, opening windows if weather allows and using fans or dehumidifiers to dry carpets quickly so that carpets are completely dry within 24 hours.
- Disposing of cleaning solutions properly.

In general, extraction-cleaning should not be used for carpets that have an underlay due to the difficulty of removing water.

4.2.4. Food Areas

Cafeterias, lunchrooms and office areas where food is consumed are places where special care is needed to minimize bacteria and pests. In most areas across Canada, applicable provincial and municipal health standards will include sanitation requirements. Food waste, garbage and recycling receptacles containing food containers and debris need to be emptied regularly and be kept clean. Refrigerators, food preparation areas and dish washing facilities need to be kept clean.

4.2.5. Restrooms

Restrooms must be cleaned frequently using appropriate cleaning products. Ensure that cleaning is done thoroughly, including hard-to-reach areas such as behind toilets and around urinals. Restroom floors should periodically be machine-scrubbed with a sanitizer or disinfectant. Make sure that appropriate dilutions are used and recommended dwell times are followed to allow for sanitizing to be thorough.

Many products used for restroom cleaning, such as drain cleaners and toilet bowl cleaners (see Section 5 *Cleaning Products),* can be quite hazardous. Make sure that appropriate personal protective equipment is used. Follow these suggestions:

- Clean from high to low, towards the doorway, and do dry work before wet work;
- Prepare the area and place a 'Restroom Closed' sign at the door, if applicable;
- Clean the exterior of all dispensers and re-stock supplies, including paper towel dispensers, feminine hygiene dispensers, toilet tissue dispensers and hand soap dispensers;
- Remove all waste from receptacles;
- Clean receptacles with a sanitizer cleaner; and
- Dust mop or sweep the floor, and pick up collected debris with dustpan.

4.2.6. Indoor Plants

Indoor plants are often used in buildings to personalize work spaces and to add interest to public areas. When plants are not well-maintained, pests like aphids and spills from the watering of plants can affect air quality. For this reason it is recommended that plants only be permitted when the facility manager or tenant has a maintenance program that ensures proper care and watering. Plants on carpets should have blocks underneath to keep moisture from reaching the carpet and unit ventilators should not be used as plant stands. All plants should have secondary basins that retain excess water.

5. Cleaning Products

5.1. Selection of Cleaning Products

Cleaning is an essential activity. By its nature, cleaning involves removing physical contaminants and disinfecting, and therefore the use of chemicals for which we currently have limited knowledge about their effects on IAQ and on health. Given our incomplete knowledge, the goal is then to strive for a balance between effectiveness, effect on indoor air quality, labour and cost. There is no definitive list of cleaning products that maximize cleaning effectiveness while minimizing substances that can adversely affect indoor air quality. Table 3-2 (page 8) provides general information about attributes and ingredients. It is recopied from the U.S. Environmental Protection Agency (EPA) and is only an example of

the type of information that is available. It should be used with discretion, as the terms "Preferred attributes" and "Preferred ingredients" are relative. Where custodial services are done under contract, the terms should specify the desired attributes of cleaning products.

5.2. Measuring/Diluting Concentrated Cleaning Products

Highly-concentrated cleaning products must be handled, stored and mixed (diluted) according to manufacturers' directions. This can be achieved through a variety of methods including measuring cups, simple dispensing pumps and more complicated automatic dilution equipment. Follow these recommendations:

- Clearly post mixing instructions in janitors' rooms;
- Use appropriate protective equipment when mixing concentrated cleaning products;
- Follow manufacturer's dilution directions - do not under- or over-dilute concentrated cleaning products;
- Make sure secondary containers have appropriate label; and
- Never mix different cleaning products together.

Cleaning personnel should understand that adding extra concentrated cleaning product does not make it work better or faster. It wastes products and can also result in longer times to do a job (i.e., removing residues), slippery floors and surfaces, accumulations of chemical residues and other complications. The residue of most cleaning products attracts and retains dirt and may cause skin irritation and respiratory distress in some people.

5.3. Storage of Cleaning Products

The storage of cleaning products in well-designed and ventilated janitorial closets is an important aspect of an overall strategy to minimize IAQ impacts resulting from cleaning and maintenance. Provision of hot water taps and adequate mop sinks, proper dispensing systems for stock cleaning agents, moisture-resistant flooring materials, posted instructions for the preparation of cleaning agents, and protocols in well-located closets will assist in the delivery of improved cleaning services.

See references in section 9 for additional sources of information.

5.4. Janitorial Equipment

Vacuum cleaners should be equipped with a high-efficiency particulate air (HEPA) filtration system capable of trapping 99.97% (>0.3 μm) of all airborne particles collected by the vacuum.

5.5. Smoking Areas

Smoking areas should be located away from building entrances and away from ventilation intakes. It is important to provide clear signage for both designated smoking areas and areas where smoking is not permitted. Consult local bylaws for required distances. Information about smoking areas is available from:

Canadian Centre for Occupational Health and Safety (http://www.ccohs.ca/oshanswers/psychosocial/ets_resolutions.html)

Table 3-2 Selection of cleaning products	
Product Category	**Suggestions ***
All-purpose cleaners	Preferred attributes pH close to 7; biodegradable; no or low levels of dyes and fragrances; no or low VOC emissions; detergent-based (not solvent-based) products compared to those containing solvents. Preferable ingredients Surfactants containing terms such as lauryl, amides, and glycosides Less-preferable ingredients Nonyl phenol ethoxylates, NTA, EDTA, glycol ethers, sodium hydroxide, potassium hydroxide, sodium metasilicate, or phosphates.
Carpet cleaners	Preferred attributes Same as all-purpose cleaners and not sticky when dry.
Chrome cleaner/ polish	Products frequently contain petroleum distillates, which adversely affect indoor air quality. Preferred Attributes Low VOC emissions, natural oils. Less-preferable ingredients Petroleum distillates, ammonia.
Floor finishes	Preferred attributes Durable so as to minimize application frequency; compatible with stripping products used. Preferable ingredients Containing cross-linked polymers. Less-preferable ingredients Containing heavy metals requiring heavier duty strippers.
Floor strippers	Preferred attributes See Floor Finishes. Products for removing floor finishes containing heavy metals typically have high pH, solvents and ammoniated compounds necessary to remove metal cross-linked floor finishes. Strippers must be compatible with the floor finish, have a pH close to neutral, no or low VOC emissions, containing naturally-derived solvents. Preferable ingredients D-limonene (citrus solvent) and methyl esters. Less-preferable ingredients Ethylene glycol mono butyl ether (butyl cellusolve), 2-butoxyethanol, ammonia, and sodium hydroxide.

Table 3-2 Selection of cleaning products	
Product Category	**Suggestions ***
Furniture polishes	Many furniture polishes contain petroleum distillates, which adversely affect indoor air quality. Preferred attributes Low VOC compared to products with higher levels; contain natural oils such as citrus (lemon and orange) oils.
General degreasers	Products typically contain petroleum-based solvents, which can be can be flammable and have high VOC emission rates. Preferred attributes No or low VOC emissions. Preferable ingredients d-Limonene (derived from citrus fruits); and methyl esters from soy and corn. Less-preferable ingredients Glycol ethers in general; ethylene glycol mono butyl ether (butyl cellusolve); and sodium hydroxide.
General disinfectants	General disinfectants are similar to All-purpose cleaners but have additional ingredients to kill bacteria and organisms. They are toxic and may be persistent in the environment and accumulate in living tissue. Preferable ingredients Antimicrobial ingredients that have a lower potential for accumulating in living tissue; hydrogen peroxide. Less-preferable ingredients Sodium hypochlorite (chlorine bleach), quaternary ammonium compounds and phenolic compounds.
Glass cleaners	Products have ingredients that evaporate quickly such as alcohol, glycol ethers or ammonia. The best choices have the following attributes: Preferred attributes no or low VOC emissions; detergent-based; high flashpoint; neutral pH (closer to 7); no or low levels of dyes and fragrances. Preferable ingredients Surfactants containing lauryls, amides, or glycosides. Less-preferable ingredients Ammonia; alcohols; propylene glycol; ethylene glycol and other glycol ethers.

Table 3-2 Selection of cleaning products	
Product Category	**Suggestions ***
Graffiti removers	Many products use propellants (e.g., propane, butane), which are highly flammable and can contribute to indoor air quality problems. Preferred attributes No or low VOC emissions; detergent-based; high flashpoint; and neutral pH (closer to 7). Preferable ingredients n-Methyl-2-Pyrolidone; d-Limonene. Less-preferable ingredients Less preferable ingredients: methylene chloride, petroleum distillates, propane, butane, isobutene, and sodium hydroxide.
Gum removers	Preferred attributes No or low VOC emissions; detergent-based; high flashpoint; neutral pH (closer to 7). Preferable ingredients Dry ice; carbon dioxide. Less-preferable ingredients Freon; dichloro-difluoromethane; and trichloro-fluoromethane.
Lime and scale removers	Products are acids because of the need to remove mineral deposits from sinks, bowls and urinals. Preferred attributes Mild acid (in the range of 4 or higher). Preferable ingredients Citric or acetic acid. Less-preferable ingredients Hydrochloric or phosphoric acid.
Spot removers	Preferable ingredients Detergent-based.
Urinal deodorizers	Minimize use through more frequent cleaning. Preferred attributes Readily biodegradable (many older formulations present serious environmental and health concerns). Preferable ingredients Surfactants containing terms such as lauryl, amides, glycosides. Less-preferable Nonyl phenol ethoxylates, and paradichlorobenzene.

* The information contained in this table is recopied from the U.S. Environmental Protection Agency (EPA) and is only an example of the type of information available. It should be used be used with discretion, as the terms “Preferred attributes” and “Preferred ingredients” are relative.

5.6. Storage of Hazardous Gases, Dusts or Liquids

Materials such as paints and solvents are fire risks and potential sources of VOC emissions. Storage areas should be clean and ventilated to the exterior. The National Building Code requires that "spaces that contain hazardous gases, dusts or liquids shall be designed, constructed and installed to conform to the requirements of the applicable provincial or territorial regulations or municipal bylaws or, in the absence of such regulations or bylaws, to good engineering practice such as that described in the publications of the NFPA or the NFC." [NFPA: National Fire Protection Association, *Fire Protection Guide to Hazardous Materials*, 2001 Edition, NFPA Standard 30-2008, *Flammable and Combustible Liquids Code.* NFC: National Fire Code of Canada] (NBC 6.2.2.6.).

To reduce emissions, follow these recommendations:

- Safely discard products that are old, outdated or no longer required in accordance with municipal hazardous waste disposal requirements.
- Store paints and solvents in approved containers and areas.
- Keep containers closed when not in use.
- Where more than 100 L of flammable liquids in small containers are present, keep them in a storage cabinet approved by the National Fire Protection Association (NFPA).

For additional information, see sources such as LEED User, Indoor Chemical and Pollutant Source Control: http://www.leeduser.com/credit/NC-v2.2/EQc5

6. Maintenance

6.1. Cleaning HVAC Systems

The HVAC system is a crucial aspect of indoor air quality. For detailed information about HVAC operation, refer to Module 5, *Hygienic Operation of Air Handling Systems*.

The HVAC system requires adequate preventive maintenance (PM) and timely repairs to operate correctly and provide a comfortable environment with acceptable indoor air quality. HVAC system operators must have an adequate understanding of the overall system design, its intended function, operational requirements, and its limitations. The PM program must be properly budgeted and implemented, not merely planned on paper.

A well-implemented PM plan will improve the functioning of the mechanical systems and usually save money when evaluated on a lifecycle basis. However, in some buildings, because of budgetary constraints, lack of knowledge, or poor management, maintenance is delayed until breakdowns occur or complaints arise. Such practice often increases operational costs and could result in IAQ problems.

HVAC maintenance practices vary depending on the type of equipment, building types, and existing envelope measures, as well as building location, size, use pattern, and purpose. This makes it difficult to establish a single set of maintenance practices.

A clean mechanical room, free of tracked-in dirt and stored chemicals, is an important element in the prevention of indoor air quality problems. The state of the mechanical room is often an indicator of the care and commitment of the building operator. Airborne contaminants in the mechanical room can be drawn into ductwork through return air openings or unsealed seams in return ducts and be circulated throughout a building.

6.2. Ducts

Any duct cleaning should be scheduled during periods when the building is unoccupied to prevent occupant exposure to chemicals and loosened particles. The air handling unit should not be used during the cleaning or as an air movement device for the cleaning process. The National Air Duct Cleaning Association recommends that the system should be run to allow at least eight air changes in the occupied space after duct cleaning has been completed.

Negative air pressure that will draw pollutants to a vacuum collection system should be maintained at all times in the duct cleaning area to prevent migration of dust, dirt, and contaminants into occupied areas. Where possible, use vacuum equipment or fans during cleaning and sanitizing to make sure that cleaning vapours are exhausted to the outside and do not enter the occupied space.

Air duct after cleaning

If it is determined that ductwork should be cleaned, careful attention must be given to protecting it and its interior surfaces (especially insulation and sound attenuating devices).

When gaining access to sheet metal ducts for cleaning purposes, it is essential to seal access holes properly in order to maintain the integrity of the HVAC system. Use existing duct system openings where possible because it is difficult to repair the damage caused by cutting new access entries into the ductwork. Access doors are recommended if the system is to be cleaned periodically, and all access locations should be identified on the building's mechanical plans.

Duct cleaning performed with high velocity airflow should include gentle, well-controlled brushing of duct surfaces or other methods to dislodge dust and other particles. Duct cleaning that relies only on a high velocity airflow through the ducts is not likely to achieve satisfactory results because the flow rate at the duct surface remains too low to remove many particles. Vacuum equipment should be used with care because high negative pressure can collapse ducts.

Since duct cleaning requires high volumes of air, seasonal timing is crucial. In cold or hot weather when high amounts of space conditioning are required, HEPA filtration and interior discharge of dust cleaning air will reduce make-up air requirements and energy costs.

Only HEPA filtered vacuuming equipment should be used if the vacuum collection unit is inside the occupied space or discharges to the space. Conventional vacuuming equipment may discharge extremely fine particulate matter back into the atmosphere, rather than collecting it. Duct cleaning equipment that draws dust and dirt into a collection unit outside the building is also available. People should not be allowed to remain in the immediate vicinity of these collection units.

If biocides are to be used, a written rationale and application plan should be prepared in advance. Select only approved products, use the products according to the manufacturer's directions, and pay careful attention to the method of application.

Careful cleaning and sanitizing of any parts of coils and drip pans can reduce microbiological pollutants. Prior to using sanitizers, deodorizers, or any cleansing agents, carefully read the directions on the product label. Once cleaned, these components should be thoroughly rinsed and dried to prevent exposure of building occupants to the cleaning chemicals.

Water-damaged or contaminated porous materials in the ductwork or other air handling system components should be removed and replaced. Even when such materials are thoroughly dried, there is no way to guarantee that all microbial growth has been eliminated.

After the duct system has been cleaned and restored to use, a preventive maintenance program will prevent the recurrence of problems. Such a program should include particular attention to the use and maintenance of adequate filters, control of moisture in the HVAC system, and periodic inspection and cleaning of HVAC system components.

The National Research Council (NRC) has conducted an evaluation of the effectiveness of duct cleaning. A report entitled "Testing Effectiveness of Duct Cleaning and Its Impact on Airborne Particles, Mold and Biocide Levels in Commercial Office Buildings" is available at http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdoc&an=20374769&article=0&fd=pdf.

6.3. Filters

Filters that are not changed when required (based on their design loading and maximum allowable pressure drop) can become a bed for fungal growth, sometimes allowing particles or microorganisms to be distributed within the building. As filters are increasingly loaded, the fans use more energy to operate and move less air.

Clean air filters increase airflow through the system, resulting in improved system efficiency, indoor air-quality, and better occupant satisfaction. One of the simplest and most effective methods of increasing an HVAC system's airflow and efficiency is to inspect and replace system air filters according to manufacturers' recommendations.

Measures must be taken to control the migration of dust and other contaminants

7. Repair and Renovation

7.1. Planning

Renovation, redecorating, and remodelling activities can create indoor air problems by producing dust, odours, airborne bacteria, mould spores and chemical emissions. It is difficult to prevent IAQ problems if some building areas are undergoing renovation while adjoining areas continue normal operations. Advance planning, area isolation plans, worker access and other details must be identified and resolved before starting work.

Materials used for repair and renovation should follow the same selection principles as materials selected for new construction. However, with repairs and renovations, emissions from materials and processes occur in enclosed spaces, usually managed by an operating HVAC system, and regular building occupants may be present in areas adjoining renovations.

Renovation is an opportunity to assess the previous selection of products in relation to IAQ and make choices that improve the work environment. As for new construction, materials exposed in a building interior should have surfaces that can be easily cleaned. Ensuring that these surfaces are also durable will reduce maintenance requirements as well as the IAQ impacts associated with replacement or refinishing. Particular attention should be paid to appropriate selection of flooring materials and surfaces used in restrooms.

7.2. Space Reorganization

Modern ventilation systems are custom-designed to suit space layout and occupancy. Layout changes may require changes to the HVAC system. For example, if two office spaces designed for 2 or 3 people are converted to a meeting room with a capacity for 10 or so people, the HVAC will need to be modified accordingly.

8. Removal and Replacement of Materials

8.1. Hazardous Materials

Many types of hazardous materials that could adversely affect air quality may be encountered during repairs or renovations (see Table 3-3, page 16). It is important to determine what hazardous materials are present before undertaking any work. Investigation and removal of these materials requires special knowledge and outside expertise will likely be required. If any hazardous materials are encountered, contact the local building officials before removing or disturbing them. Proper inspections, review of existing information, and planning will minimize unexpected problems during renovations.

8.2. Resolving Moisture-related Problems

Mould is the common word for any fungus that grows on damp materials. It can be black, white or almost any colour. It often looks like a stain or smudge and it may smell musty. In order to grow, mould needs moisture and a material it can live on. It then releases “spores” and metabolic by-products into the air which are small enough to be inhaled. Breathing in large amounts of these spores and the by-products they produce can negatively impact health. Common places for mould to grow indoors are on improperly constructed building assemblies, window sills, fabrics, carpets, bathrooms, laundry areas, ceilings, basements, crawl spaces and walls near food preparation areas.

The key to preventing mould is preventing excessive moisture through proper maintenance. Further advice from Health Canada can be found here: http://www.hc-sc.gc.ca/hl-vs/alt_formats/pdf/iyh-vsv/environ/air-eng.pdf.

Micro-organisms can also occur in HVAC systems, facilitating their spread through the ventilation system. The National Building Code of Canada (NBC) A-6.2.2.5.(3) notes:

Sources for microbial growth causing hypersensitivity, pneumonitis and humidifier fever include drain pans, spray-water air-washers, contaminated filters, poorly maintained cooling coils, water incursion into ductwork, cafeteria dishwasher drainage leaks, high humidity and stagnant water. Some of the control measures are as follows:

(a) Drain pans should be pitched toward the drain outlet and the outlet bottom should be flush with the drain pan bottom, otherwise there will be standing water in the pan, exposed to the supply air passing through the cooling section of the air-handling unit.

(b) Access into air-handling equipment should be provided for maintenance of filters, cooling coils and condensate drain pans located below the cooling coils. Access doors should be large and easy to open to facilitate thorough and regular maintenance. Hinged access doors are preferable to bolted access panels.

(c) If moisture is added to commercial building ventilation air (such as in hospital operating rooms and dedicated computer rooms) to maintain humidity levels in a designated range (for example, 40% to 50% relative humidity), humidifiers that inject steam or water vapour into central air-handling units or main supply ducts are normally used. Injection nozzles should not be located in air-handling unit plenums or ductwork that is insulated with internal fibrous lining. If the lining becomes wet, conditions conducive to microbial growth will result.

The NBC recommendations only address built-in features of an HVAC system that can help to minimize growth of micro-organisms. Even more important than the built-in features is a program of regular maintenance and cleaning of those portions of the system where such growth is likely to occur. Information sources for mould include:

Health Canada, Mould and Your Health: http://www.hc-sc.gc.ca/fniah-spnia/promotion/public-publique/home-maison/mould-moisissure-eng.php

Canadian Centre for Occupational Health and Safety, Indoor Air Quality - Moulds and Fungi: http://www.ccohs.ca/oshanswers/biol_hazards/iaq_ mould.html

New York City Department of Health, Guidelines on Assessment and Remediation of Fungi in Indoor Environments: http://www.nyc.gov/html/doh/html/epi/ mouldrpt1.shtml

Health Canada, Fungal Contamination in Public Buildings: Health Effects and Investigation Methods: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/fungal-fongique/index_e.html

Canada Mortgage and Housing Corporation (CMHC), Fighting Mould - The Homeowners' Guide: http://www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/momo/momo_005.cfm

Canadian Construction Association, Mould Guidelines: http://www.cca-acc.com/documents/cca82/cca82.pdf

National Collaborating Centre for Environmental Health (NCCEH), Mould Assessment and Remediation in Indoor Environments:
Assessment: http://www.ncceh.ca/sites/default/files/Mould_Assessment_May_2010.pdf

Remediation: http://www.ncceh.ca/sites/default/files/Mould_Remediation_May_2010.pdf

Table 3-3 Dealing with hazardous materials

Material	Description	Information sources
Radon	Radon is a naturally occurring radioactive gas present in soil and rock. Radon migrates through the soil and groundwater and can enter buildings through cracks or other openings in their foundations. Its decay products can cause lung cancer. The current guideline specified by Health Canada, is 200 Bq/m^3 as an annual average concentration and this threshold is reflected in the 2010 National Building Code.	Government of Canada Radon Guideline: http://www.hc-sc.gc.ca/ewh-semt/radiation/radon/guidelines_lignes_directrice-eng.php
Asbestos	Asbestos was once used for its fire-resistant and mechanical properties for applications such as pipe insulation, stucco, ceiling tiles and flooring Undisturbed, it generally does not pose a problem. If it is must be removed or disturbed as part of a repair or renovation, expert assistance will be required. In some jurisdictions, buildings containing asbestos must have an asbestos management plan.	EPA, Building Air Quality: A Guide for Building Owners and Facility Managers: http://www.epa.gov/iaq/largebldgs/pdf_files/iaq.pdf Provincial occupational health and safety regulations
PCBs	PCB stands for polychlorinated biphenyl. For several decades, PCBs were used widely as ingredients in many industrial materials, such as sealing and caulking compounds, cutting oils, inks and paint additives. PCBs were also used to make coolants and lubricants for certain kinds of electrical equipment, such as transformers and capacitors. There are strict regulations for the handling, storage and disposal of PCBs.	Health Canada, It's Your Health – PCBs: http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/pcb-bpc-eng.php Provincial occupational health and safety regulations
Mould	Mould can result from poor moisture management and is frequently encountered during roof, ceiling, window, and toilet area renovations.	Canadian Construction Association, Mould Guidelines: http://www.cca-acc.com/documents/cca82/cca82.pdf
Lead	Buildings built before the mid 1980's may have paint with lead. Buildings built prior to 1960 are more likely to contain higher levels of lead in paint. Removing or disturbing lead paint could expose people to serious health risks.	Health Canada, Lead Information Package: http://www.hc-sc.gc.ca/ewh-semt/contaminants/lead-plomb/asked_questions-questions_posees-eng.php

8.3. Selection of Replacement Materials

Repairs and renovations, like new construction, provide the opportunity to review the life cycle performance requirements of the system. Redesigning allows renewed consideration of costs, but also of on-going maintenance requirements, durability, moisture susceptibility, and other factors that will impact the performance and service life of the system.

Many building materials, finishes, and furnishings emit chemical compounds that can cause discomfort, irritation, or other more serious health impacts, including (VOCs. Selecting appropriate materials, finishes, and furnishings reduces the likelihood of emissions-related IAQ problems. Emission rates and patterns vary significantly depending on materials. Liquids such as paint and varnish tend to have very high early emissions that decay rapidly (within hours or days), while others may release contaminants at nearly constant rates for many months. Absorbent materials such as carpets, gypsum board, and ceiling tile can store VOCs from other materials while indoor air concentrations are high and release them over time, when concentrations are lower.

Checklist 3-2 shows strategies that will help minimize emissions from building materials used for repairs and renovations. Table 3-4 lists some types of products and materials that can be high VOC emitters and provides selection recommendations.

Checklist 3-2 Strategies for reducing emissions from repair and renovation materials

1. Plan work staging, product storage and site issues to minimize cross contamination of components through storage or work practices.
2. Protect materials from contamination during storage and installation.
3. Specify products known to minimize emissions (see Table 3-4).
4. Require the submission and review of material characteristics (VOC contents or, preferably, detailed emissions properties) as condition of acceptance of repair and renovation materials.
5. Require detailed installation, maintenance, and cleaning instructions as part of the material acceptance process.
6. Limit the use of porous/fleecy materials including carpeting, fabrics, and upholstery to reduce sink effects and facilitate cleaning.
7. Select materials that are durable and low-maintenance and have easily cleanable surfaces.
8. Verify that product installation practice conforms to project specifications.
9. Immediately following installation of new ductwork, seal all duct openings to prevent contamination during construction and remove the seals prior to system activation.
10. Use low-emission cleaning agents to remove any residual oils on the interior surfaces of ductwork prior to installation.
11. Provide good ventilation throughout construction to keep contaminant concentrations low.
12. Plan ventilation and air movement so the flow moves from “clean” areas tto “dirty” areas.
13. Ensure that detailed maintenance and cleaning instructions are provided prior to commissioning.
14. Use a commissioning checklist (see Checklist 3-3).

Table 3-4 Selection of building materials and products

Material	Suggestions	Information Sources
Caulks, sealants and adhesives	These products can be high emitters while they are curing. Specify products that are labelled as being low in VOC emissions.	LEED User: http://www.leeduser.com/credit/NC-2009/IEQc4.1 California, Building Material Emissions Study: http://www.calrecycle.ca.gov/Publications/GreenBuilding/43303015.pdf
Paints and coatings	Paint, stain, varnish and lacquer coatings can be very high VOC emitters for the first few days after application. Select water-based products, but recognize that they also release contaminants. Consider pre-finished components or finishing components off-site.	LEED User: http://www.leeduser.com/credit/NC-v2.2/EQc4.2 California, Building Material Emissions Study: http://www.calrecycle.ca.gov/Publications/GreenBuilding/43303015.pdf
Carpet and underlay	Select carpets that carry a CCI Green Label	Canadian Carpet Institute: http://www.canadiancarpet.org/carpet_and_health/air_quality/green_label_program.php LEED User: http://www.leeduser.com/credit/CI-2009/IEQc4.3 California, Building Material Emissions Study http://www.calrecycle.ca.gov/Publications/GreenBuilding/43303015.pdf
Composite wood materials (particleboard, MDF (medium density fibreboard)) and others	Use interior grade panels that are not made with urea-formaldehyde adhesives.	LEED User: http://www.leeduser.com/credit/NC-v2.2/EQc4.4 California, Building Material Emissions Study: http://www.calrecycle.ca.gov/Publications/GreenBuilding/43303015.pdf

8.4. Installation of Replacement Materials

8.4.1. IAQ Management during Renovation

The most effective means to reduce the impact of material emissions is to employ selection strategies that limit the entry of high-emitting materials into the building (i.e., source control through appropriate material selection). The products used in building construction and furnishing will still emit some level of contaminants, and certain materials with relatively high emissions may be unavoidable due to a lack

of alternative products or due to emission-generating activities. For example, laminates, veneers and some liquid-applied coatings can be used to reduce emissions from underlying emitting materials such as particleboard and MDF (medium-density fibreboard). To reduce the negative impact of these materials/activities on the indoor environment, a number of strategies can be employed, such as LEED User: http://www.leeduser.com/credit/NC-v2.2/EQc3.1Control of Chemical Emissions.

8.4.2. Material Conditioning

Airing new materials in a well-ventilated, clean space prior to installation in a building can be an effective means of reducing the typically high emissions that characterize new materials. Off-site opening of wrapped or tightly packaged materials to facilitate this "conditioning" phase is an important aspect of this simple strategy.

Products that have been formulated to undergo a curing process that will result in reduced contaminant emissions can be sought during material selection. This is particularly relevant for products such as caulks, sealants, and adhesives that must be applied in wet form and for which effective in-place curing can have greatest benefit.

8.4.3. Staged Entry of Materials

To the extent practical, install materials that are high early emitters (e.g., coatings, caulks, adhesives, and sealants) in stages so that the ventilation of emissions can be controlled.

As much as possible, schedule the installation of materials that are known to absorb and store contaminants (sinks) such as textiles, carpet and underlayment, drywall, acoustical ceiling tiles, open-plan office partition panels, and insulation materials to reduce their ability to store emissions from other installed materials.

8.4.4. Exhaust of Unavoidable Emissions

It is important to have good general ventilation during renovations and to protect the HVAC system and building assemblies from contamination. Local ventilation can be used to exhaust emissions from materials in the early stages when emissions are highest.

8.4.5. Isolation of Dust

During the installation of new materials, barriers should be used to contain dust in the work areas and to keep dust and debris from entering ductwork.

8.4.6. Filtration and Air Cleaning

Gas-phase or particle-phase filtration can, if applied to HVAC system return airstreams, assist with the removal of IAQ contaminants. Filtration to remove ozone from the outdoor air can reduce the formation of ultra-fine particulates and gaseous irritants formed through reaction with IAQ contaminants.

8.4.7. Building Flush-out

At completion of a repair or renovation, contaminant emissions from building materials and interior surfaces are typically at their highest. It is useful to operate the building HVAC systems at a higher than normal ventilation rate for a period of time to help flush the building of these contaminants prior to occupancy and even during initial occupancy. The specific flush-out procedure employed must be adapted to local climatic/seasonal conditions.

Building bake-out (heating interior space to between 35 and 39°C in an attempt to speed emissions from materials and finishes) is discouraged because the effect has been shown to be temporary, tends to merely redistribute contaminant sources, and may damage building materials.

8.4.8. Delayed Occupancy

Delay occupancy of renovated areas as long as practicable so that early-phase product emissions have dissipated.

8.4.9. Occupancy after Repairs and Renovations

Treat a building or building area where repairs or renovations have been completed using a formal commissioning as would normally be used in the commissioning of a new building. Checklist 3-3 shows tasks that should be completed prior to occupancy, including items specific to indoor air quality. The completion of other items not directly related to indoor air quality may provide time for additional dissipation of air contaminants, in addition to adding to overall safety and comfort.

Checklist 3-3 Requirements prior to occupancy

1. All construction materials and debris removed from the building.
2. All systems (fire, lighting, electrical and mechanical) functional such that no further alterations are required.
3. All work completed in compliance with contract specifications.
4. Air handling systems clean, balanced and operational.
5. Primary and secondary clean-up completed.
6. Ventilation operational for __ days prior to occupancy.
7. Communication with tenants/occupants about building operation.
8. Review and modify the new IAQ profile (Module 8).

9. Sources of Additional Information

1. Building Air Quality: A Guide for Building Owners and Facility Managers: http://www.epa.gov/iaq/largebldgs/pdf_files/iaq.pdf
2. Pennsylvania Green Building Maintenance Manual: http://www.mass.gov/Eoaf/docs/dcam/maf-ma/manuals/o_and_m_pa_green_bldg_o&m_manual.pdf
3. Indoor Air Quality: A Guide for Building Owners, Managers, and Occupants, Work Safe BC: http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/indoor_air_bk89.pdf
4. Environmental Tobacco Smoke (ETS): Workplace Policy, Canadian Centre for Occupational Health and Safety: http://www.ccohs.ca/oshanswers/psychosocial/ets_resolutions.html

5. LEED Reference Guide for Green Building Operations and Maintenance: http://www.gbci.org/Libraries/Credential_Exam_References/LEED-for-Operations-and-Maintenance-Reference-Guide-Introduction.sflb.ashx

6. A Guide to Green Operations and Maintenance, Stopwaste.org: http://stopwaste.org/docs/gbmg-dec-20-07ltr.pdf

7. California Department of Public Health, Indoor Air Quality Program: http://www.cal-iaq.org/

8. LEED User: http://www.leeduser.com/browse

9. Green Cleaning Product Procurement Policies, Initiatives, and Requirements in the U.S.: http://www.issa.com/data/files/articles/88/greenprocure.pdf

10. EcoLogoM Program, Cleaning & Janitorial Products Category: http://www.ecologo.org/en/greenproducts/professional/