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Air Infiltration and Ventilation Centre

Indoor Air Pollutants

Part 2: Description of sources and control/mitigation measures

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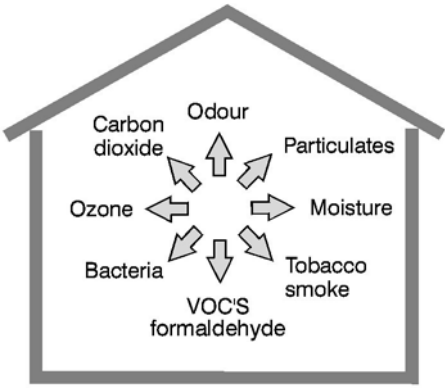

1 Introduction

VIP Indoor Air Pollutants, Part 1 defined major types of indoor air pollutants, their measurement, and concentrations guidelines [Ref. 1].

This VIP addresses the sources of pollutants and effective measures to control them or to mitigate their impacts on occupants and building contents. The most effective means to control indoor air pollution is through reduction or elimination of pollution sources. Indoor pollutants originate both within the building and from outside. The first step in controlling the sources of indoor air pollution is to identify them. Building materials, occupants and their activities, and equipment and appliances can all be sources of indoor pollutants. Once the sources have been identified, control strategies can be developed and implemented. Appropriate ventilation strategies can reduce concentrations of pollutants that can't be eliminated by source control. Air cleaning and filtration can reduce the concentrations of contaminants in buildings where ventilation systems recirculate air within the building.

For an introductory discussion of indoor air pollutants and concentrations, see reference 1.

2 Pollutant sources

2.1 Indoor sources

Controlling indoor air pollutants requires knowing their sources.

Most indoor air pollutants come from a variety of sources and activities indoors. These include housekeeping and maintenance products, occupant-related activities and sources, building use-related sources, building-related sources, HVAC systems, and others. Many of these sources can be controlled fully or partially while others cannot. Table 1 identifies pollutants commonly found in offices and many other building types and their sources within the buildings.

2.2 Outdoor sources

Outdoor air can be a source of pollutants from motor vehicle exhaust, commercial and manufacturing sources, public works/utilities, agriculture, construction, building maintenance, building exhaust, birds and rodents, ground and water sources. Contaminants from these sources frequently find their way inside through the building exterior, door and window openings, or other pathways. The best way to avoid contamination from outdoor air pollutants is to carefully locate the building away from such sources and to locate building ventilation air intakes distant from pollution sources.

Table 1 : Selected major indoor pollutants and potential sources

Chemicals, pollutants, or pollutant class	Potential sources
Environmental Tobacco Smoke	Lighted cigarettes, cigars, pipes
Combustion by-products	Furnaces, generators, gas or kerosene cooking appliances and unvented space or water heaters; candles; outdoor air; vehicles.
Biological contaminants: mold, bacteria, viruses, pollen, dust mites, shed skin cells, body odors	Wet or damp materials, cooling towers, humidifiers, cooling coils or drain pans, damp duct insulation or filters, condensation, re-entrained sanitary exhausts, bird droppings, cockroaches or rodents, dust mites on upholstered furniture or carpeting ...
Volatile Organic Compounds (VOCs)	Paints, stains, varnishes, solvents, pesticides, adhesives, wood preservatives, waxes, polishes, cleansers, lubricants, sealants, dyes, air fresheners, fuels, plastics, copy machines, printers, tobacco products, perfumes, dry cleaned clothing, laundry products.
Formaldehyde	Particleboard, plywood, cabinetry, furniture, fabrics.
Soil gases (radon, sewer gas, VOCs, methane)	Soil and rock (radon), sewer drain leak, dry drain traps, leaking underground storage tanks, land fill
Pesticides and other semi-volatile organic chemicals	Termiticides, insecticides, rodenticides, fungicides, disinfectants, herbicides.
Particles and Fibers	Printing, paper handling, smoking and other combustion, outdoor sources, deterioration of materials, construction/renovation, vacuuming, insulation.

Particle filters and gaseous pollutant removal media can be used in cases of strong pollution sources to control entry of polluted air into occupied spaces. For more information, see reference 2.

3 Indoor pollutant mitigation measures

It is generally agreed that the most effective strategy for controlling exposure to indoor pollutants is to eliminate or reduce the sources. Once the effective source reduction strategies are implemented, then ventilation can be used to reduce concentrations and to control exposures. The fewer and weaker the sources, the less ventilation will be required to maintain concentration below a given level. This is evident from the plot in Figure 1 showing the influence of contaminant source strength and ventilation on concentration. Contaminant source strength is defined in terms of mass emitted per unit area per unit of time. This is represented in the graph as the emission factor, EF, and is in units of milligrams per square meter per hour (mg/m² h).

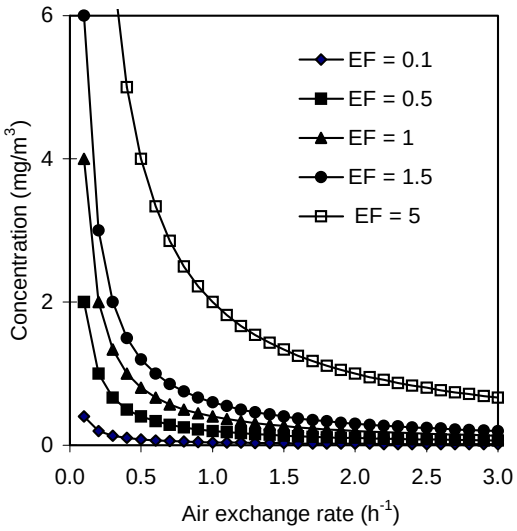

Figure 1 : Relations between source strength, ventilation rate, and pollutant concentrations

3.1 Pollutant mitigation

The major approaches to pollutant mitigation are source control, ventilation, and air cleaning/filtration. The most effective method in terms of occupant protection, overall efficiency, and energy conservation is source control.

3.2 Source control

In order to address sources effectively, it is necessary to identify the major sources and consider means to minimize them in building design and operation or during mitigation of an IAQ problem. Major sources of indoor pollutants can be classified into the following categories:

- Housekeeping and maintenance products;
- Occupant-related sources;
- Building uses;
- Building related sources;
- HVAC system;
- Moisture;
- Vehicles.

During design, pollutants can be mitigated by selection of materials that have the lowest and least hazardous emissions, by isolating sources and providing exhaust ventilation to prevent contamination of other building spaces, and by providing ventilation proportional to the expected sources.

Table 2 a-g list various common sources of indoor air pollutants and ways to limit the emissions.

Table 2: Indoor pollutant sources and potential mitigation measures

Table 2 a: Housekeeping and maintenance

Category/common sources	Tips for mitigation and control
• Cleansers • Waxes and polishes • Disinfectants • Air fresheners • Adhesives • Janitor's/storage closets • Wet mops • Drain cleaners • Vacuuming • Paints and coatings • Solvents • Pesticides • Lubricants	• Use low-emitting products – some manufacturers and trade associations now provide information on product emissions • Avoid aerosols and sprays • Dilute to proper strength (manufacturer's instructions) • Do not overuse; use during unoccupied hours • Use proper protocol when diluting and mixing • Store properly with containers closed and lid tight • Use exhaust ventilation for storage spaces (eliminate return air) • Clean mops: store mop top up to dry • Avoid “air fresheners”— clean and exhaust instead • Use high efficiency vacuum bags/filters • Use Integrated Pest Management (See Section 4)

Table 2 b: Occupant-related sources

Category/common sources	Tips for mitigation and control

• Tobacco products
• Office equipment
  o Computers
  o Printers
  o Copiers
• Cooking/microwave
• Art supplies
• Marking pens
• Paper products
• Personal products (e.g., perfume)
• Tracked in dirt/pollen
	• Smoking policy
	• Use exhaust ventilation with pressure control for major local sources
	• Low emitting art supplies/marking pens
	• Avoid paper clutter
	• Educational material for occupants and staff

Table 2 c: Building uses as major sources

Category/common sources	Tips for mitigation and control
• Print/photocopy shop • Dry cleaning • Science laboratory • Medical office • Hair/nail salon • Cafeteria • Pet store	• Use exhaust ventilation and pressure control to maintain negative pressure in spaces with strong sources • Use exhaust hoods where appropriate; check hood airflows

Table 2 d: Building-related sources

Category/common sources	Tips for mitigation and control
• Plywood/composite wood products • Construction adhesives • Asbestos products • Insulation • Wall/ floor coverings (vinyl/plastic) • Carpets/carpet adhesives • Wet building products • Transformers • Upholstered furniture • Renovation/remodeling	• Use low emitting products– some manufacturers and trade associations now provide information on product emissions • Air out in an open/ventilated area before installing • Increase ventilation rates during and after installing • Keep material dry prior to enclosing • Use renovation guidelines (see Section 4) • Perform polluting activities during unoccupied hours

Table 2 e: HVAC system

Category/common sources	Tips for mitigation and control

• Contaminated filters
• Contaminated duct lining
• Dirty drain pans
• Humidifiers
• Lubricants
• Refrigerants
• Mechanical room
• Maintenance activities
• Combustion appliances
  o Boilers/furnaces
  o DHW
  o Generators
  o Stoves
	• Perform HVAC preventive maintenance
	• Use filter change protocol
	• Clean drain pans; proper slope and drainage
	• Use potable water for steam humidification
	• Keep duct lining dry; move lining outside of duct if possible
	• Fix leaks/clean spills (see filter change protocol)
	• Maintain spotless mechanical room (not a storage area)
	• Avoid back drafting
	• Check/maintain flues from boiler to outside
	• Keep combustion appliances properly tuned
	• Disallow unvented combustion appliances
	• Perform polluting activities during unoccupied hours

Table 2 f: Moisture

Category/common sources	Tips for mitigation and control
• Mold	• Keep building dry • Develop and implement a Mold and Moisture Control Protocol (see Section 4)

Table 2 g: Vehicles

Category/common sources	Tips for mitigation and control
• Underground/attached garage • Outdoor air	• Use exhaust ventilation • Maintain garage under negative pressure relative to the building • Check air flow patterns and pressure relationships between spaces and between building and garage or outdoors frequently • Monitor CO

4 Available technologies: protocols for managing major sources of pollution in buildings

There are a number of protocols that can be followed to control the major sources of pollution in buildings. The general categories are listed in Table 3, and details are given in the sections of the Table 4.

Table 3 : Type of protocol

• Remodeling and renovation • Painting • Pest control *Integrated pest management* • Shipping and receiving • Establish and enforce a smoking policy • Smoking lounge requirements • Managing moisture and mold

Table 4 : Protocols to manage building pollution source activities

(Situations vary considerably from building to building and even over time in the same building. Therefore, it is important to recognize that not all of the protocols listed in this table will be applicable necessarily to all space or all the time to any space)

Table 4 a: Remodeling and renovation

Use effective strategies for material selection • Obtain manufacturer data on VOC content emissions and select low VOC content and low VOC emitting products • Use manufacturers recommendations for cleaning and maintenance of surfaces as part of product selection criteria Use effective strategies for material installation • Isolate construction activity from occupants. • Use adequate ventilation during and after installing “wet” products • Seal or otherwise protect ventilation system ductwork and textile surfaces during installation of wet products or procedures that generate dust.

Table 4 b: Painting

Establish a protocol for painting and ensure that the protocol is followed by both in-house personnel and by contractors.

- Avoid painting occupied spaces whenever possible- Paint during unoccupied hours.
- Use low VOC emission, fast drying paints where feasible.
- Keep lids on paint containers when not in use.
- Ventilate the building with significant quantities of outside air during and after painting.

Ensure a complete building flush prior to occupancy.

- Use more than normal outside air ventilation for some period after occupancy.
- Avoid spraying, when possible.

Table 4 c: Pest control - Integrated pest management

- Use or require the use of Integrated Pest Management by pest control contractors in order to minimize the use of pesticides when managing pests.
    - Control dirt, moisture, clutter, foodstuff, harborage, and building penetrations to minimize pests.
    - Use baits and traps rather than pesticide sprays where possible.
    - Avoid periodic pesticide application for “prevention” of pests.
    - Use pesticides only where pests are located.
    - Use pesticide specifically formulated for the targeted pest.
- Apply pesticides only during unoccupied hours.
- Ventilate the building with significant quantities of outside air during and after applications.
- Insure a complete building flush prior to occupancy.
- Use more than normal outside air ventilation for some period after occupancy.
- Notify occupants prior to re-occupancy.
- If applying outside, keep away from air intake.

Table 4 d: Shipping and receiving

Establish and enforce a program to prevent vehicle contaminants from entering the building.

- Do not allow idling of vehicles at the loading dock. Post signs and enforce the ban.
- Pressurize the receiving area relative to the outside to insure that contaminants from the loading area do not enter the building. Use pressurized vestibules and air locks if necessary.
- Periodically check the pressure relationships and compliance with the protocol.
- Notify delivery company supervisors of policy.

Table 4 e: Establish and enforce a smoking policy

Environmental Tobacco Smoke (ETS) is a major indoor air contaminant. A smoking policy may take one of two forms:

- A smoke-free policy which does not allow smoking in any part of the building.
- A policy that restricts smoking to designated smoking lounges only.

(Partial policies such as allowing smoking only in private offices are not effective.)

Table 4 f: Smoking lounge requirements

A designated smoking lounge must have the following features to be effective in containing ETS.

- The lounge should be fully enclosed.
- The lounge should be sealed off from the return air plenum.
- The lounge should have exhaust ventilation directly to the outside at 100 m^3/h per occupant (using maximum occupancy).
- Transfer air from occupied spaces may be used as make up air.
- The lounge should be maintained under negative pressure relative to the surrounding occupied spaces.
- The doors to the lounge should be automatic sliding doors.

Table 4 g: Managing moisture and mold
(Also see EPA's Mold Remediation Guideline http://www.epa.gov/iaq/molds/index.html)

Mold thrives in the presence of water. The secret to controlling mold is to control moisture and relative humidity

- Keep relative humidity (RH) below levels that will result in condensation on cool or cold surfaces. This requires knowing the temperature and humidity of the air and the dewpoint. Some guidelines exist, but they depend on the relationship between indoor temperature and humidity and the surfaces inside the space. Cool surfaces become subject to condensation when the dewpoint of the air is lower than the temperature of available surfaces. Relative humidities below 60% are generally the recommended maximum, but RH below 50%, where feasible, will be more effective to control dust mites.

Keep all parts of the building dry that are not designed to be wet

- Adequately insulate exterior walls or ceilings as necessary to maintain interior surfaces warm enough to avoid condensation on cold surfaces
- Insulate cold water pipes to avoid sweating
- Clean spills immediately. Thoroughly clean and dry liquid spills on porous surfaces such as carpet within 24 hours, or discard the material
- Do not allow standing water in any location
- Maintain proper water drainage around the perimeter of the building
- Provide sufficient exhaust in showers or kitchen areas producing steam

Thoroughly clean areas that are designed to be wet

- Wash floors and walls often where water accumulates (e.g., showers)
- Clean drain pans often and ensure a proper slope to keep water draining
- Ensure proper maintenance and treatment of cooling tower operations

Discard all material with signs of mold growth

- Discard furniture, carpet, or similar porous material having a persistent musty odor
- Discard furniture, carpet, or similar porous material that has been wet for more than 24 hours
- Discard ceiling tiles with visible water stains

5 Ventilation

After all reasonable efforts to control sources are in place, there will still be contaminants in the air – from people, building materials, occupant activities, and other sources. Ventilation is used to dilute contaminants to acceptable concentration levels. See Part One of this VIP for more information on concentrations of concern and guideline values [Ref 1]. Ventilation is treated extensively in numerous AIVC publications, *e.g.*, A Guide to Energy Efficient Ventilation, AIVC, 1996 [Ref. 3].

6 Pollution transport

Contaminants reach occupant breathing-zones by traveling from the source to the occupant by various pathways. Normally, the contaminants travel with the flow of air. Air moves from areas of high pressure to areas of low pressure. That is why controlling building air pressure is an integral part of controlling pollution and enhancing building IAQ performance. Air movement should be from occupants, toward a source, and out of the building rather than from the source to the occupants and out the building. Pressure differences will control the direction of air motion and the extent of occupant exposure.

The investigation, design, and management of pollutant transport focuses on driving forces and pathways. Major driving forces include the wind, stack effect, HVAC/fans, flues and exhaust, and elevators. The major indoor pathways include stairwell, elevator shaft, vertical electrical or plumbing chases, receptacles, outlets, openings, ducts or plenums, duct or plenum leakage, flue or exhaust leakage, and room spaces. The major outdoors-to-indoors pathways include indoor air intake, windows/doors, cracks and crevices, substructures and slab penetrations. [Ref. 2]

7 References and further reading

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.