Health Canada Santé Canada

AIR

Office Air

A Worker's Guide to Air Quality in Offices, Schools, and Hospitals




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A Worker's Guide to Air Quality in Offices, Schools, and Hospitals

A Report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health

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Our mission is to help the people of Canada
maintain and improve their health.
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Copies of this booklet are available from:

Communications Directorate
Health Canada
Tunney's Pasture
Ottawa, Ontario
K1A 0K9

Authors
Dan Clarke – Alberta Workers' Health, Safety and Compensation
Dennis Nikkel – Manitoba Department of Labour

Editors
Marla Sheffer (English)
Monique D'Amour (French)

Departmental Secretariat
Marc Bourgeau
David Green

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Foreword

Government agencies across Canada have been receiving calls from people who are concerned about the quality of the air in their place of work. These people want to know the cause of the various physical symptoms they are experiencing. As well, they want practical advice to help find a solution to their indoor air quality problems.

If you are an office building occupant or one of the personnel responsible for the administration and management of building maintenance, you should find this booklet useful. The guidance provided is also applicable to similar-use areas in both schools and hospitals. However, you should not use this booklet for industrial-use areas of these buildings, such as laboratories, maintenance shops, print shops, woodworking shops, or automotive shops. The standards outlined in provincial and federal occupational health and safety legislation should be applied in these cases.

As indoor air quality problems are often very complex, this booklet may not have all the answers you require. However, the government agencies listed in Appendix A of the booklet can provide you with further advice. A bibliography, listing other useful publications, is provided in Appendix B.

Using This Booklet

To carry out an effective investigation of indoor air quality problems in your building, you will first need to learn about some common causes and effects of indoor air quality problems. Part 1 of this booklet provides basic information about the effects of poor indoor air quality, factors affecting indoor air quality, and the need for effective communication when resolving indoor air quality problems.

Part 2 presents a simplified approach to the investigation of indoor air quality based on the practical experience of government investigators from across Canada. The first step in the process is making an educated guess (or forming a theory) about what you think might be the cause of complaints in your building. You form this theory by carrying out a preliminary walkthrough of your building and answering some basic questions about the building. The second step in the investigative process is the testing of your theory to see if it was right.

Sometimes you will still be unsuccessful in identifying the cause of your indoor air quality complaints, even after you have completed all the steps in Part 2. If you have not succeeded in resolving complaints at this point, you will likely have to bring in some expert help. Part 3 provides some practical advice on how to hire a professional consultant.

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Part 1:
Introduction to Indoor Air Quality Problems

A. What Are the Effects of Poor Indoor Air Quality?

Indoor air quality has become an important occupational and environmental health issue. The number of complaints related to indoor air quality has increased with the trend toward more tightly sealed buildings and energy conservation measures that recirculate building air and reduce the amount of outside air supply. The growing use of synthetic materials, modern office equipment (photocopiers, laser printers, computers), cleaning products, and outdoor air pollution also contribute to indoor air contamination.

The physical symptoms commonly attributed to indoor air quality problems include headache, fatigue, shortness of breath, sinus congestion, cough, sneezing, skin irritation, dizziness, nausea, and eye, nose, and throat irritation. Some individuals may be particularly susceptible to the effects of indoor air contaminants, for instance:

- allergic or asthmatic individuals
- people with respiratory disease
- people whose immune systems are suppressed due to chemotherapy, radiation therapy, disease, or other causes, and
- contact lens wearers

Children and people with asthma may also be very susceptible to the effects of indoor air contaminants. Studies show that children exposed to environmental tobacco smoke, for example, are at a higher risk of respiratory illness. Asthma sufferers are more susceptible to some pollutants that may trigger an allergic reaction.

The term "sick building syndrome" is sometimes used to describe the cases in which occupants of a building experience short-term effects that seem to be linked to the time they spend in the building. In buildings where these effects have been observed, measurement of air pollutants often fails to reveal high concentrations of any one contaminant. The problem is then often thought to be the result of the combined effects of many pollutants at low concentrations, with other environmental factors complicating the problem.

For example, there are factors that interfere with how warm or how cold a person feels. These thermal comfort factors include overheating, underheating, humidity extremes, drafts, and lack of air circulation. Similarly, odours are often associated with a perception of poor air quality, whether or not they cause symptoms. Other factors in the environment, such as noise, vibration, overcrowding, and poor workplace design and lighting, can produce symptoms that may be confused with the effects of poor air quality. Physical discomfort, repetitive or boring work, and poor relationships with co-workers or superiors are all factors that can add to job stress, resulting in reduced tolerance for substandard air. Sick building syndrome relates to the combined effects of all of these factors on the building's occupants.

"Building-related illness" is another term often used to describe a recognizable illness that can be attributed directly to a building's air quality. Hypersensitivity pneumonitis (an allergic reaction) and Legionnaire's disease are examples of building-related illnesses that can be life-threatening.

B. What Factors Affect Indoor Air Quality?

The indoor environment results from the interaction of the physical layout of the site, the outdoor climate, the building's heating, ventilation, and air conditioning (HVAC) system, potential contaminant sources, and the building's occupants. Some of the sources of factors affecting indoor air quality are listed in Table 1.

The physical layout of the building, along with the building's HVAC system, will decide the most important pathway and driving force for air movement in the building. All of the building's parts (e.g., walls, ceilings, floors, and HVAC equipment) interact to affect the distribution of pollutants. For instance, room dividers can act to limit and contain air movement. This lack of air circulation may result in the concentration of contaminants within a small area, even if total ventilation to

the room is adequate. Location of a work station between a smoking room and the building air return vent, for example, can result in higher levels of tobacco smoke in that area.

Table 1.
Sources of Factors Affecting Indoor Air Quality and Comfort

Factor	Source
Microbial matter	Stagnant water in HVAC system, wet and damp materials, humidifiers, condensate drain pans, water towers
Carbon dioxide*	People, combustion of fossil fuels (e.g., gas or oil furnaces and heaters)
Carbon monoxide	Auto exhaust (garages, loading docks, air intakes), combustion, tobacco smoke
Formaldehyde	Unsealed plywood or particleboard, urea formaldehyde foam insulation, fabrics, glues, carpets, furnishings, carbonless copy paper, new or remodelled areas of buildings
Particulates	Smoke, street dust (e.g., cement) through air inlets, paper, duct insulation, water residue, tobacco products, carpets, HVAC filters
Volatile organic compounds (VOCs)	Copying and printing machines, carpets, furnishings, cleaning materials, smoke, glue, adhesives, caulking, perfumes, hairsprays, paints, solvents
Inadequate ventilation	Energy-saving and maintenance measures, improper system design or operation, occupant tampering with HVAC system, poor office layout
Temperature and humidity extremes	Improper placement of thermostats, poor humidity control, inability of the building to compensate for climate extremes, tenant-added office equipment and processes

* Carbon dioxide is not a factor that directly affects a building's indoor air quality or comfort. Rather, it is often used as a surrogate measure of building ventilation rate (see Section C1 in Part 2 for a complete explanation).

The outdoor climate can also have an impact on indoor air quality. In regions with cold outdoor climates, modern HVAC systems often reduce the supply of fresh outdoor air to save on heating costs. In addition, when the outside air temperature is low, it is often harder to maintain comfortable relative humidity levels. Large differences between inside and outside temperatures can result in condensation problems in buildings that were not designed to operate at high humidity levels. Sometimes it will be impossible to achieve recommended relative humidity levels in these buildings.

A good HVAC system is designed to provide thermal comfort (temperature and humidity control), distribute outdoor air to occupants, and remove odours and contaminants. It accomplishes these tasks by using fans to exhaust or dilute contaminants to acceptable levels and by controlling pressure relationships between rooms. However, indoor air quality problems may result when these systems were not designed for the way the building is used, are poorly maintained, or are impaired in some way. Good ventilation alone will not always ensure good indoor air quality. The sources of pollution within the building must also be controlled.

The building's occupants themselves can also have a major influence on indoor air quality problems. People can become a source of contaminants through smoking, cooking, body odour, and cosmetic odours.

C. Communicating Indoor Air Quality Problems

Often many of the problems associated with indoor air quality complaints can be magnified by poor communication. If complaints from a building's occupants are ignored, the situation can escalate into a crisis. Simple solutions to problems in a building are often missed if the investigator fails to include occupants in the investigation.

If you wish to resolve indoor air quality complaints quickly, you first need to establish a communication plan for the building. Your communication plan should include procedures for handling complaints and for communicating information before, during, and after the investigation. Lines of communication should identify key people involved in the investigation (occupants, building staff, management, health and regulatory agencies, etc.). Cooperation and early action can lead to a successful solution. Without open communication, any indoor air quality problem can become complicated by frustration and distrust, delaying its resolution.

Because standards of comfort vary from one individual to another, it is probably impossible to satisfy all occupants of a building. However, it is in everyone's best interests for you to respond promptly and seriously to all complaints about the indoor environment. Trust can be established only through open communication with the building's occupants. You should not underestimate the anxiety and frustration that can result if occupants believe that no action is being taken or that important information is being withheld. The best communication strategy for resolving indoor air quality complaints is to involve the building's occupants in the process to find a solution.

For effective communication during indoor air quality investigations, it is good practice to include the following steps:

1. Define where complaints are concentrated (the extent of the complaint area may be revised as time goes on).
2. Establish a system of recording the timing and location of complaints. This could include complaint logs and/or occupant questionnaires. Written records are important in understanding indoor air quality problems.
3. Identify key people and form key relationships. Occupants of the building can be valuable allies in solving indoor air quality problems, particularly in observing patterns of discomfort, including odours. To encourage this cooperation, it is advisable to get occupants to participate actively in the investigation by asking them to collect this information.
4. Notify occupants of the building of all actions taken to remedy a complaint.
5. Follow up with the building's occupants to ensure that the corrective action has resolved the problem.

Part 2:
Resolving Indoor Air Quality Problems

A. How to Use Part 2

In Section B of this part of the booklet, you are asked to carry out a preliminary walkthrough of your building and to answer some basic questions about the building. The responses to these questions will help you form an idea about the likely cause of your indoor air quality problems. Section C gives you more detailed guidance on testing your theory to see if you were right. If you find that your first idea was wrong or that correcting the problem did not alleviate complaints, you should continue with testing your next theory. As poor indoor air quality rarely results from a single cause, it is likely that you will have to repeat this procedure several times with different theories.

By checking out your theories one at a time until the cause of the problem in your building is identified and eliminated, you can reduce wasted effort and the need for expensive testing. It makes no sense, for example, to carry out a complete chemical analysis of the air in a building when you can see that the air intake for the building is located near the exhaust vent of a dry-cleaning operation.

If you exhaust all the possibilities listed in this booklet and you have still not solved the problem, you will likely need to bring in some professional help. Use the flow chart in Figure 1 to lead yourself through the investigative process.

B. Carrying Out a Preliminary Building Walkthrough

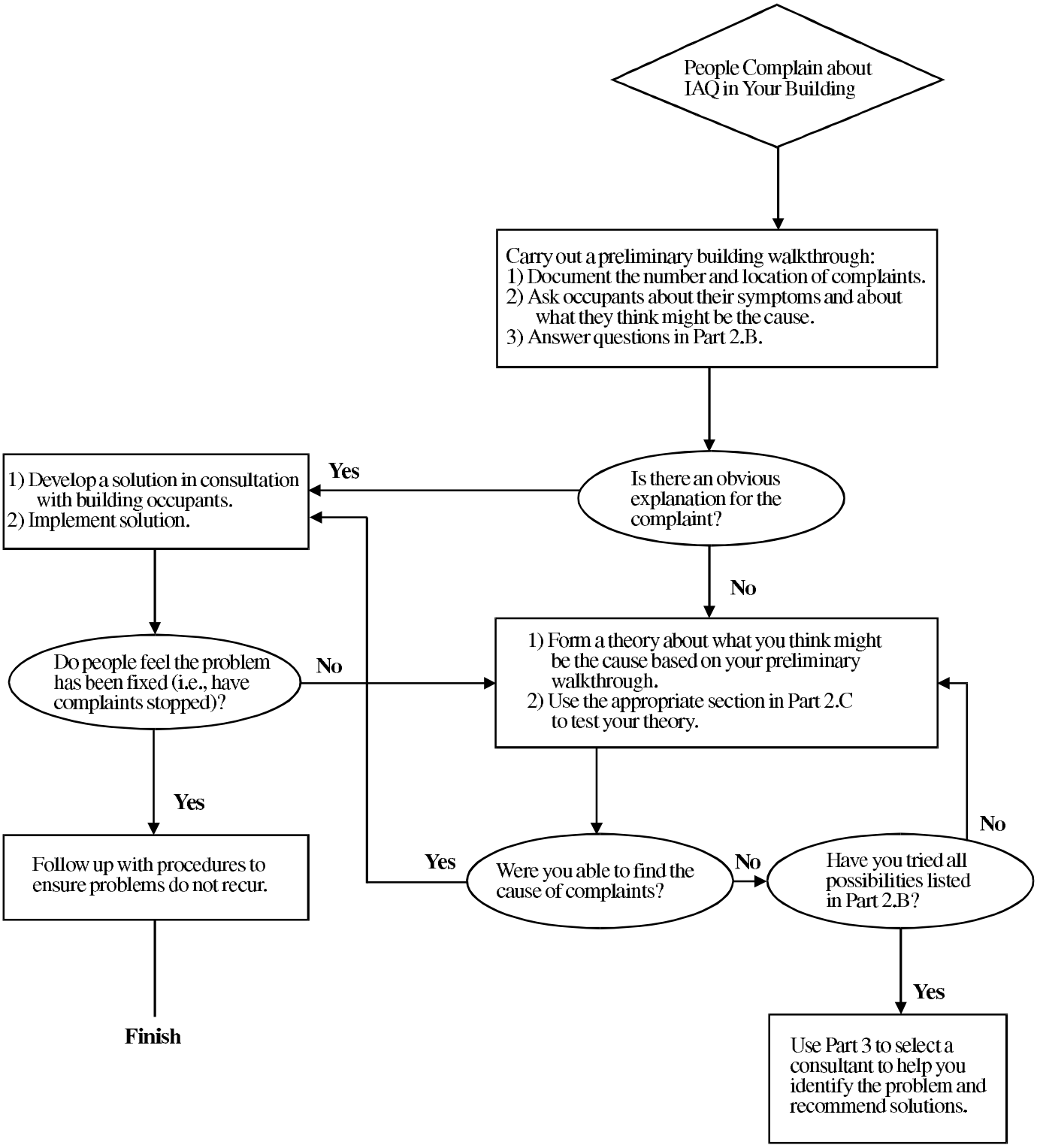
The preliminary building walkthrough is a fact-finding exercise to document complaints. Obvious problem areas should be identified and corrected immediately. Your intent should be to obtain as much background information as is practical on the building.

During this initial assessment, you should identify:

- the things people complain about most (e.g., odours, dryness, symptoms)
- the number of people who complain
- building activities that are related by timing, location, etc., to individual complaints
- any signs of people interfering with the HVAC system (e.g., blocked openings), and
- obvious internal and external pollutant sources.

If the specific source of the problem has been identified and a solution proposed, the investigation should stop at this point. If the source cannot be found, it is necessary to proceed with the more detailed investigation described in Section C of Part 2.

Figure 1.
Resolving Indoor Air Quality Problems



Use this flow chart to lead yourself through the process of investigating indoor air quality problems in your building.

In the following sections, you are provided with some questions regarding the common factors that can affect indoor air quality. Use the questions to help you form a theory about the likely causes of your indoor air quality problems. A "yes" answer to any of the questions means that you should carry out a more detailed evaluation in that area.

B1. Heating, Ventilation, and Air Conditioning (HVAC) System

- Has the building's HVAC system been poorly maintained (i.e., has no regular maintenance schedule been established)?
- Do occupants complain that they find the room or building too stuffy or dusty?
- Is the building being occupied and used differently from the way it was originally intended?
- Has there been any renovation to the building's HVAC system?
- Is the building's air intake located next to the building's exhaust stack?
- Do occupants notice identifiable odours from outside sources (e.g., cooking odours from a nearby restaurant)?

B2. Temperature and Humidity

- Do occupants complain that they find the building's air too dry, humid, hot, or cold?
- Have the building's occupants brought in portable space heaters or humidifiers?
- Has the building's maintenance staff failed to routinely monitor temperature and humidity levels?

B3. Air Motion

- Do people complain that they find the building's air too drafty or stagnant?
- Have the building's ventilation supply or return vents been blocked?
- Has the building's original design been altered by the addition of new walls or temporary room dividers?

B4. Carbon Monoxide

- Do people complain of headaches, decreased alertness, or nausea when they spend long periods of time in the building?
- Is the building's air intake located near a source of carbon monoxide (e.g., by the loading dock or by the exhaust vent for the parking garage)?
- Are there any combustion sources within the building?

B5. Formaldehyde

- Do the building's occupants complain that they are experiencing eye irritation, dry or sore throats, nosebleeds, or headaches?
- Have there been any recent renovations in the building involving installation of plywood, particleboard, or new furniture?

B6. Particulates

- Do people complain of eye, nose, or throat problems, contact lens problems, skin irritation, or respiratory difficulties?
- Is smoking allowed in the building in areas that do not have a separate ventilation system?
- Does the building's ventilation system have a filtering system that has not been maintained at the intervals recommended by the manufacturer?
- Is there a dirt build-up around diffusers?

B7. Volatile Organic Compounds

- Do the building's occupants complain of solvent odours?
- Is the building less than a year old, or has any area been renovated, repainted, or received new furniture within the past month?
- Do any of the activities carried out in the building involve the use of large amounts of chemicals (e.g., copying or blueprinting)?

B8. Micro-organisms

- Has there been an increase in the number of illnesses among the building's occupants, especially asthmatic and "flu-like" illnesses?
- Is there evidence of mould or fungal growth on building materials or in the building's ventilation system?
- Is there evidence of a previous flood or water leak in the building?
- Are there mouldy or rotten-smelling odours?

C. Developing and Testing Your Theory

Each of the following sections provides more detailed information about the suspected causes of the problems you identified in Section B. Use the sections that apply to the cause or causes you suspect to find out about the nature of the pollutant, the type of information to be collected during a more detailed assessment, and some practical suggestions to help resolve the problem.

C1. Heating, Ventilation, and Air Conditioning (HVAC) System

Indoor air quality complaints can often be caused by a lack of ventilation. However, the total amount of air supplied and removed is not the only way that HVAC systems can affect a building's air quality. Ventilation systems can also bring in outdoor contaminants and move pollutants around the building. For instance, in multi-bay buildings such as strip malls, it is common to locate an industrial process beside a retail outlet.

Air exhausted by a furniture stripping operation can be brought into a neighbouring insurance broker's office by the building's HVAC system. Once inside the broker's office, the pollutants are distributed to the different office areas. When reviewing the HVAC system's performance, look at both the supply and distribution of air. You should also consider the quality of the air supplied, especially the levels of pollutants, the temperature, and the humidity.

Start your assessment of the HVAC system by first reviewing any available documents on the history of the building — particularly relating to recent changes — and areas where complaints have been received. Ask a person familiar with the building's HVAC system to help in your investigation. The building manager or maintenance person should be a good source of information and expertise. Then look at the system itself to see if it is actually performing as designed. Check the maintenance and functioning of each component of the HVAC system. Evaluate it either as a potential source of contamination or as a component that fails to provide a necessary air handling or air conditioning function.

Carbon dioxide is a colourless, odourless gas that is often used as an indicator of how well the HVAC system works in supplying fresh air and removing contaminated air. You may wish to measure carbon dioxide if your initial check of the HVAC system turns up nothing unusual. The gas is normally present in outside air in a range from 330-350 parts per million (ppm). However, carbon dioxide concentrations in inside air are higher as a result of production from sources located within the building. The most common sources for carbon dioxide are people and combustion. People produce carbon dioxide as a by-product of breathing, and the end products of combustion are carbon dioxide and water. In buildings designed for normal occupancy, the HVAC system should be able to maintain carbon dioxide levels below about 850 ppm. This level of the gas is well below that which might start to affect people (about 5000 ppm). Carbon dioxide levels greater than 850 ppm may indicate a problem with the HVAC system's ability to remove other contaminants. The belief is that if the HVAC system is not removing the carbon dioxide, then other indoor contaminants are probably also building up in the building and the system is not providing enough fresh air.

Carbon dioxide levels should not be used as the only indicator of acceptable ventilation. There may be problems caused by localized sources of contaminants even when the level of carbon dioxide is below 850 ppm. The practice of using carbon dioxide as an indicator may also not be appropriate for areas such as school classrooms and hospital wards. In these cases, because of the large number of people present in a small area, increased carbon dioxide levels may not tell you if the other contaminants are being successfully ventilated.

If you suspect that a particular pollutant is being distributed by the ventilation system or that the building's temperature and humidity are not being properly regulated, you should also carry out a more detailed assessment as described in the appropriate section.

Assessment

When performing an assessment of the HVAC system, you should seek the assistance of the building maintenance person and:

- Learn if the way the building is currently used is the same as the use designers planned for it (e.g., was the building designed as an "open concept office" and later converted into individual offices?).
- Check to ensure that the current system can provide adequate fresh air. This is usually measured by L/sec/occupant or by $C0_2$ concentration.
- Check to see if the building's ventilation is being operated continuously or only during part of the day.
- Check the supply air fans to ensure that they are working, looking particularly for defective belts, missing blades, and build-up of particulate and microbial growth.
- Examine the supply and return air systems at several points to ensure that duct joints are properly fitted and that the system has not been tampered with.
- Examine the interior of a representative number of ducts and humidifiers for microbial growth or particulates.
- Examine the system filters for proper fit, operation, and efficiency.
- Locate and inspect the internal air handling units, and supply and return diffusers serving the complaint area.
- Inspect outside air intakes to ensure that they are not blocked or located near exhaust grills or pollution sources (see Figure 2).
- Check that all combustion sources are being exhausted.
- Verify the existence of a maintenance program for *all* HVAC components.
- Check the interior of the mixing chambers for signs of failing installation, debris, rust, or microbial growth.
- Ensure that air ducts and ceiling plenums are being maintained and cleaned.
- Check that open office space that has been changed to closed offices has been equipped with thermostats or supply air diffusers.
- Check that extra ventilation has been provided for waiting rooms, conference rooms, or high-density areas.

Once you have checked each of the above, have found nothing unusual, and still suspect a problem with the HVAC system, you may wish to measure the building's carbon dioxide levels. One of the least expensive and simplest means of measuring carbon dioxide is through the use of colorimetric tubes. These tubes change colour when air is drawn through them. Although not particularly accurate (i.e., approximately ±25%), they can be useful in determining if a detailed engineering assessment of the ventilation system is justified. The tubes are readily available through most health and safety supply companies. Care should be taken to follow the manufacturer's instructions when using the tubes, to minimize errors.

Figure 2.
Bringing Pollutants into the Building from an Outside Source

The waste disposal bins and air intakes for buildings are often located in back alleys near ground level for cosmetic reasons. This combination can lead to complaints, as "foul-smelling" air is brought into buildings. Relocation of the disposal bin will usually eliminate complaints.

Measurements should be taken at the air intake, the exhaust air plenum, places where your initial walkthrough indicated high occupancy levels and other locations where there have been complaints of poor air quality. Carbon dioxide levels at the air intake should be close to outdoor levels, otherwise exhaust is being brought into the intake. Concentrations of the gas vary considerably throughout the day, so try to take measurements during peak times when the building has been occupied for extended periods. In offices, peak carbon dioxide levels usually occur around 11:30 in the morning and 3:30 in the afternoon. Measurements in the office area should be taken about one meter above the floor and close to people's work stations.

Solutions

You can improve ventilation effectiveness if you:

- Open, adjust, or repair any of the obvious problems in the HVAC system.
- Seal leaky duct work.
- Clean duct work if dirt and debris are found.
- Remove any blockages observed in inlet and exhaust ducts.
- Change the location of occupants, of supply and return diffusers, and of furniture and partitions.
- Improve the air distribution system by increasing fan capacity in either the supply or the return system.
- Set up a preventive maintenance program for all components of the HVAC system.
- Relocate building air intakes away from pollutant sources, including building and automobile exhaust.
- Increase the supply of fresh air to the building if required.
- For industrial operations, extend the exhaust stack height well above (approximately 2 metres) the highest level of the roof, including any ventilation equipment or related mechanical structures.

C2. Temperature and Humidity

Temperature and relative humidity are two factors that affect how warm we feel. The thermal environment can also be affected by other factors such as air velocity, occupant activity level, and occupant clothing. Control of building temperature and humidity is usually achieved by the building's HVAC system. A problem in this area may also require you to carry out an HVAC system assessment (see Section C1).

Relative humidity levels below 30% are associated with increased discomfort and drying of the nose, throat, and skin, which can lead to chapping and irritation. High humidity levels can result in condensation and may cause moulds and fungi to grow. Arthritis sufferers may be affected by high humidity levels. In most Canadian cities, *ideal* indoor relative humidity levels are 35% for winter and 50% for summer.

Assessment

a. Temperature

When performing an assessment of the factors that affect building thermal comfort, you should:

- Check for any evidence of high or low temperatures. Are these due to occupant interference such as installation of heaters or new equipment?
- Check that occupants are clothed appropriately.
- Check for local sources of heating or cooling (e.g., uninsulated floors over a garage or overhang, sunshine through windows, cold window frames) (see Figure 3).
- Make sure that thermostats are working, calibrated, correctly located, and not obstructed or enclosed.
- Check for uneven air circulation and air currents. Do occupants use fans?
- Check for any obstruction of circulation such as high office partitions, taped diffusers, or perimeter units blocked by paper, books, or cabinets.

Figure 3.
Thermal Load Through Windows

The occupant in this west-facing office complained about the office temperature in the afternoons. He also complained of headaches after working awhile at the computer terminal. Installation of vertical window blinds and relocation of the computer terminal reduced both the thermal load and glare (which was causing the headaches) from the afternoon sunlight.

- Look for air supply diffusers directly over occupants or close to return slots.

b. Relative humidity

When assessing the factors that affect building humidity, you should:

- Check that the humidifier is the proper size for the building.
- Check humidifier operation. Look for excess scale or rust, fungal or mould growth, blocked nozzles, broken pump, or steam supply turned off.
- Look for a faulty or poorly calibrated humidistat located in the return air duct.
- Look for the formation of water droplets on windows or other cold objects caused by excess humidity or by not enough insulation.

Solutions

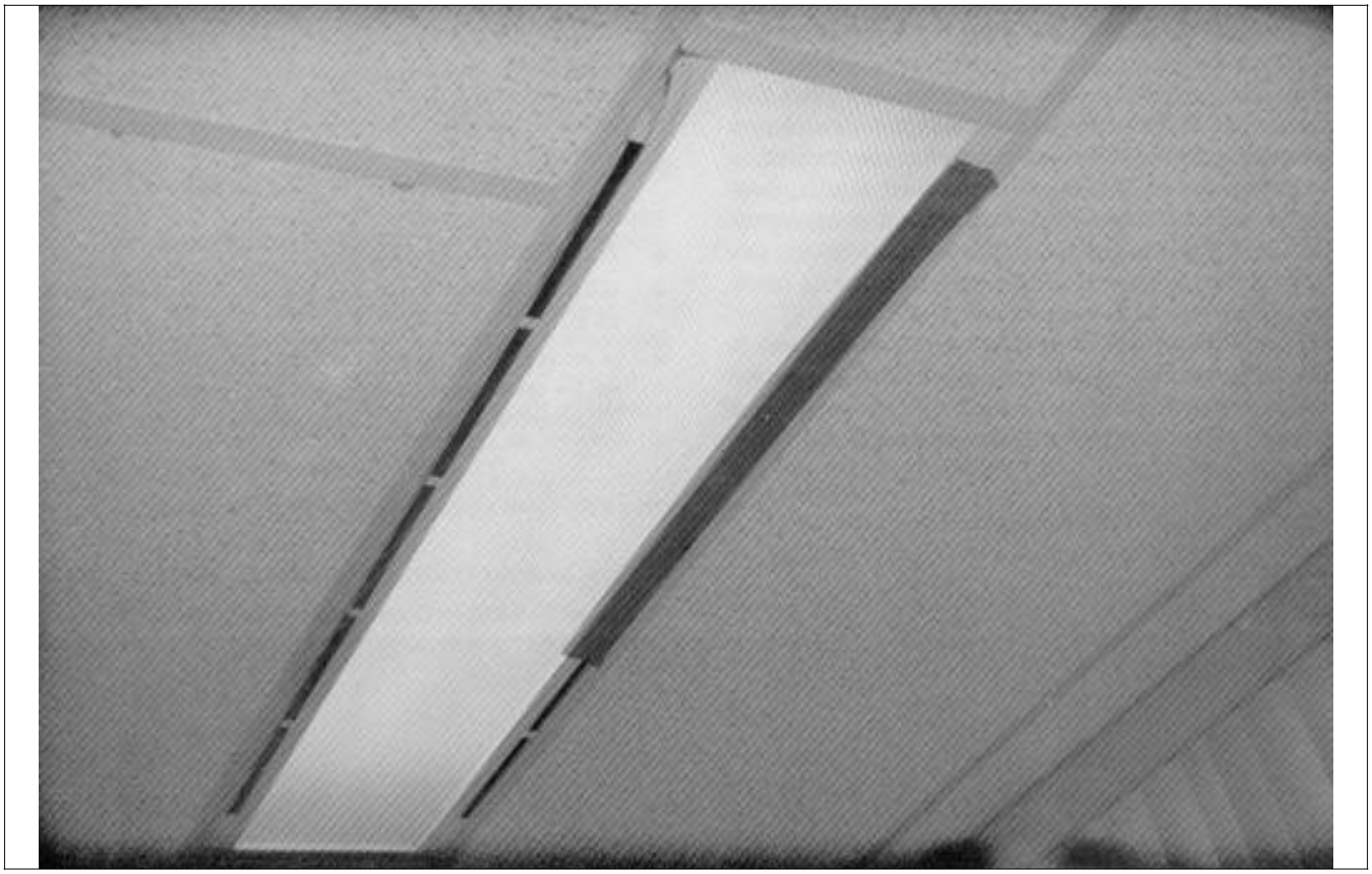
Building thermal comfort and relative humidity can be improved if you:

- Remove obstructions that block airflow (e.g., room dividers).
- Unblock diffusers and return air grilles.
- Relocate occupants away from drafts or areas that receive too much sunshine.
- Ask occupants to dress appropriately.
- Install, repair, or calibrate humidistats and thermostats.
- Install air conditioning.
- Install a humidification system.
- Establish a preventive maintenance program for temperature control and humidification systems.
- Install draperies or blinds in sunny areas (see Figure 3).

C3. Air Motion

Air motion in a building is an important comfort factor. If air motion in an occupied space is low, it may lead to complaints of stuffiness. Too much air movement causes draft, which is considered one of the most annoying factors in offices. The movement of air within the building is a function of the building's HVAC system. In this section, you are asked to look for some of the factors that relate specifically to air movement. It

Figure 4.
Blocked Air Diffusers



The occupant of this work station blocked the air diffuser because of the drafts she was feeling. The problem turned out to be the result of a change in the building interior. Relocation of office walls was completed without rebalancing the airflow to the area.

may be, however, that the problems you identify relate to the overall building ventilation, in which case you should return to Section C1.

A variety of patterns of contaminant movement are possible. The possibilities include local circulation in a room, air movement (diffusion) into nearby spaces, recirculation of contaminated air within the room or into adjacent rooms, and natural movement from lower to upper levels.

Assessment

When performing an assessment of the factors that affect air movement, you should:

- Ask about any recent change in the physical set-up and use of the space.
- Check the supply air diffusers for blockage (see Figure 4).
- See if any of the diffusers have deflectors, and check that they are adjusted properly.
- Check the return air grilles for blockages.
- Check the ceiling mixing boxes for proper control and damper positions.
- Take note of any exhaust and diffuser ducts that are near each other.
- Check the condition of filters in perimeter units and ceiling system.
- Check that duct work is in good condition and properly connected.

Solutions

Building air movement can be improved if you:

- Unblock diffusers and return air grilles where necessary.
- Deflect drafts caused by supply air diffusers with baffles.
- Rearrange movable partitions to get rid of unwanted air currents.
- Eliminate unusual air currents caused by uneven heating by adjusting partitions, insulating, or relocating the diffuser and return air grilles.
- Adjust the airflow to spaces that have been redesigned. Flow system rebalancing may be necessary.

C4. Carbon Monoxide

Carbon monoxide is a colourless, odourless, toxic gas that is a product of incomplete combustion. Pollution results when combustion gases are not properly exhausted or are reintroduced into the building. Exposure to carbon monoxide at high concentrations can be fatal. Most parking garages are equipped with carbon monoxide sensors that switch on the ventilation system when levels get above a preset point. Symptoms of low-level exposure include headaches, nausea, fatigue, and flu-like symptoms. These effects are not likely to be observed below about 25 ppm. In most buildings, levels will be below 5 ppm. Carbon monoxide levels above 5 ppm usually indicate the presence of combustion products. Whenever measurements detect the presence of these contaminants, it is important to ensure that the contaminants are exhausted at the source. The American Society of Heating, Refrigeration and Air- Conditioning Engineers recommends a maximum eight-hour average exposure limit of 9 ppm.

In office and commercial buildings, important sources of carbon monoxide include tobacco smoke, and garages and loading docks that are attached or have a pathway to working spaces. Air intake vents located at ground level or near vehicles or other combustion sources can spread contaminants to all areas served by the air handling system.

Assessment

When performing an assessment of the likelihood of carbon monoxide being a factor in your indoor air quality problems, you should look for combustion sources.

First, inspect the loading dock and parking garages to see if there:

- is proper ventilation,
- are trucks or cars left running,
- are doorways, stairways, elevator shafts, or ducts acting as pathways for vehicle exhaust to other building areas,
- are carbon monoxide sensors (for ventilation control) and alarms properly calibrated and operating, and
- is ventilation operated continuously or switched on only during peak use periods.

Then go to the office area and decide if there:

- are occupants working near possible sources of combustion products,
- are stoves or other sources not fitted with exhaust systems,
- are air intakes close to a street carrying heavy traffic, or to other exhausts containing combustion products (see Figure 5),
- are occupants complaining of symptoms such as headaches and fatigue, and
- are exhaust odours present.

You can also check for leaks in gas-fired heating systems and for back-drafting of combustion products. If you still suspect carbon monoxide, you may wish to carry out some preliminary measurements. The simplest and least expensive method of measuring the gas involves colorimetric tubes. These tubes are available from most local health and safety supply specialty stores.

Solutions

Combustion odours can suggest a serious problem. Problems can usually be corrected if you:

- Ensure all vehicle engines are turned off while inside the building.
- Remove or relocate the combustion source.

Figure 5.
Carbon Monoxide from Outside Sources

The air intake for the above building is located beside the building's receiving dock. Carbon monoxide from the truck exhaust was being brought into the building by the ventilation system. A policy allowing receiving of goods only when the ventilation system was off (before 6 a.m. and after 5 p.m.) solved the problem.

- Close pathways between the contaminated area and the occupied space, or ensure that doors are well sealed.
- Ensure that offices near parking garages and loading docks are under positive pressure.
- Increase exhaust ventilation to the problem area.

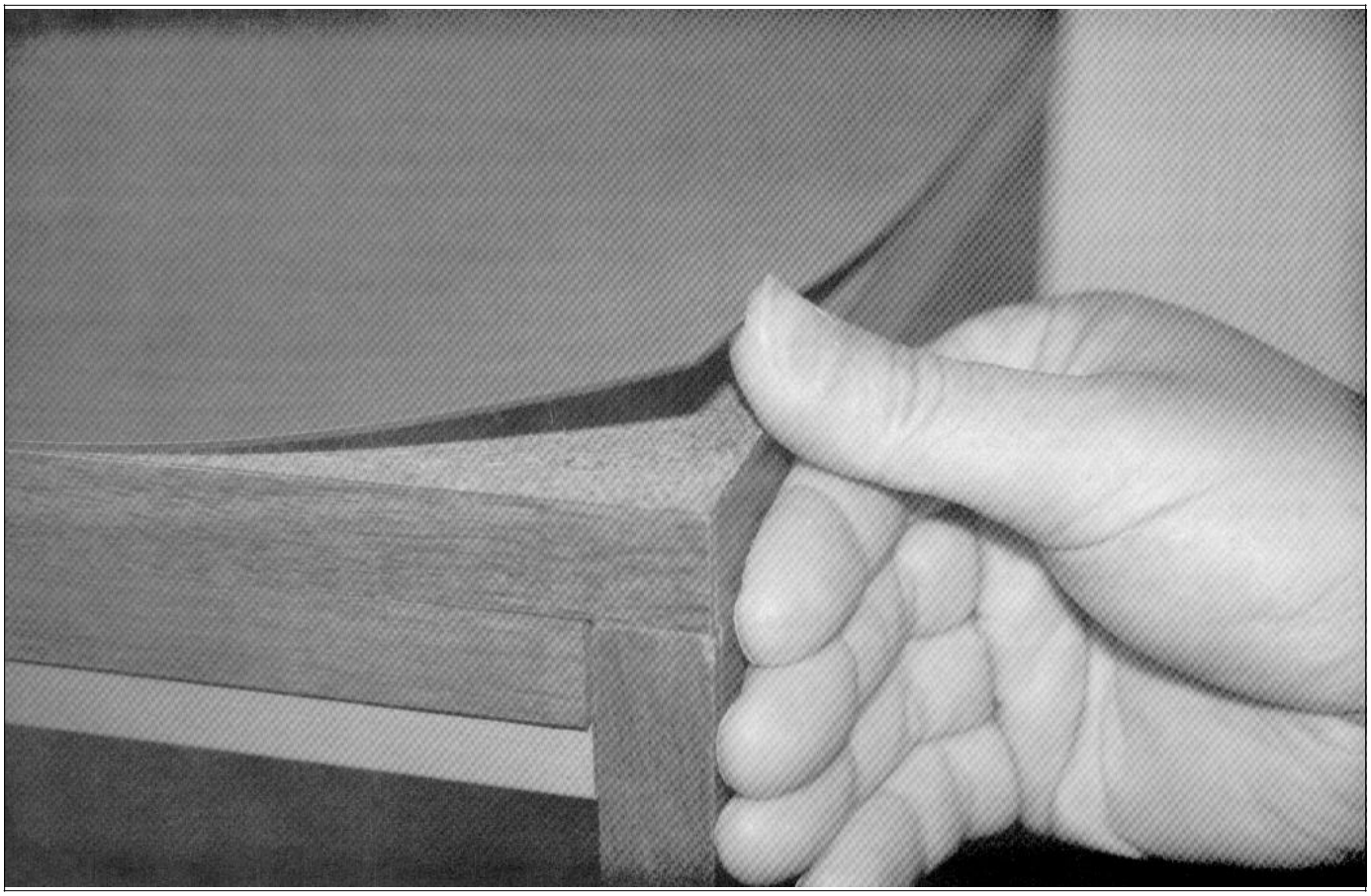
C5. Formaldehyde

Formaldehyde is a colourless gas with a pungent odour. Building materials, especially new ones, are the most common source of the gas. Carpets, particleboard, furniture, and fabrics often contain cleaning fluids or adhesives with formaldehyde in them (see Figure 6). Slow off-gassing from these building materials can result in concentrations of formaldehyde that affect a building's occupants. Formaldehyde is an example of a particularly common volatile organic compound (VOC) that is found in buildings. Complaints caused by formaldehyde can be similar to those caused by other VOCs. If you are unsuccessful in confirming that formaldehyde is the cause of your problem, you may also wish to check the other common VOC sources described in Section C7.

Indoor formaldehyde concentrations are dependent on the age of the source, changes in ventilation rate, indoor and outdoor temperatures, and humidity. Formaldehyde concentrations can also vary by 50% from day to day and from season to season.

Formaldehyde is a known irritant and sensitizer. Symptoms include dry or sore throats, nosebleeds, headaches, fatigue, nausea, dizziness, breathlessness, and burning or stinging in the eyes.

Figure 6.
Sources of Formaldehyde



The above picture shows the corner of a desk with part of the veneer removed. Both the particleboard, from which the desk is made, and the adhesive that attached the veneer to the particleboard are sources of formaldehyde. The amount of formaldehyde they give off will decrease with the age of the furniture.

Assessment

When performing an assessment of where formaldehyde may be a factor in your indoor air quality problems, you should:

- Examine records for evidence of recent changes (e.g., structural alterations, painting, installation of plywood or particleboard, replacement of carpets, installation of new furniture).
- Check on any recent changes to cleaning and maintenance procedures.

Solutions

Formaldehyde should be minimized in indoor air through both source and ventilation control methods.

Control of the source can be achieved if you:

- Remove or reduce the source by selecting products with reduced emission levels and relocating contaminant-producing materials to a better ventilated space.
- Seal the source with a barrier such as polyurethane varnish.
- Allow off-gassing of furnishings and building materials in storage before installation.

Removal of formaldehyde from the building can be improved through ventilation strategies, especially if you:

- Increase the flow of outside air during both occupied and unoccupied hours (e.g., run ventilation system continuously until levels are within an acceptable range).
- Control differences in air pressures between areas (e.g., maintaining a negative pressure in a recently renovated area of a building to prevent the release of formaldehyde into other parts of the building).
- relocate contaminant-producing materials to a better ventilated space.

Figure 7.
Isolation of the Source of Pollutants

A designated smoking room with separate ventilation is one means of containing an important source of particulates.

C6. Particulates

Particulates can be both solid or liquid matter. Dusts, fumes, smoke, and organisms such as viruses, pollen grains, bacteria, and fungal spores are examples of solid particulate matter. Mists and fog are examples of liquid particulate matter. Fibres, synthetic or natural, are also classified as particulates.

Both synthetic and natural fibres (e.g., glass wool fibres and asbestos fibres) that were used in building insulation may possibly cause cancer. Insulation that is in poor condition and located near areas where people work or beside air vents may indicate a potential insulation particulate problem. The procedures involved in assessing these problems are beyond the scope of this document. If you believe that you have an insulation particulate problem, you should contact a governmental occupational health and safety agency for advice.

Particles come from both indoor and outdoor sources and can be drawn into the building through infiltration and air intakes. The mechanical ventilation system itself may be a source of particulate matter (e.g., humidifier additives, scale, rust, disinfectants, biological growth, duct and pipe insulation).

Particulates can cause allergic reactions, dry eyes, contact lens problems, nose and throat problems, skin irritation, coughing, sneezing, and respiratory difficulties. The effects of exposure to tobacco smoke particulates include headaches and short-term irritation of the eyes, nose, and throat. Tobacco smoke is also associated with heart disease, allergies, and cancer.

Assessment

Inspections should be carried out in areas that have been recently renovated, in areas where there have been complaints, and in the mechanical room.

When assessing the likelihood of particulate contamination, you should try to decide if there:

- are sources of particulates near the building air intakes,
- are screens on the outside air dampers, and the entry is free of debris and dirt,
- are filters in place that have been properly installed and maintained,
- are sources of particulates in the humidification equipment,

- is evidence of damaged insulation in the ducts or air handling units,
- are dirt marks or white dust on diffusers, showing particulates entering from the ventilation system,
- is smoking allowed anywhere in the building, and
- are storage and movement of large amounts of paper, or paper-shredding activities.

Solutions

Control of particulate levels may be achieved if you:

- Eliminate or relocate the sources of particulates (see Figure 7).
- Locate occupants away from contaminant sources.
- Upgrade the filtering system.
- Increase the outdoor airflow.
- Avoid recirculation of air that contains contaminants.

High levels of particulates due to smoking should be controlled, ideally by banning smoking. Alternatively, you can maintain a smoking room at negative pressure, with a dedicated exhaust system.

C7. Volatile Organic Compounds

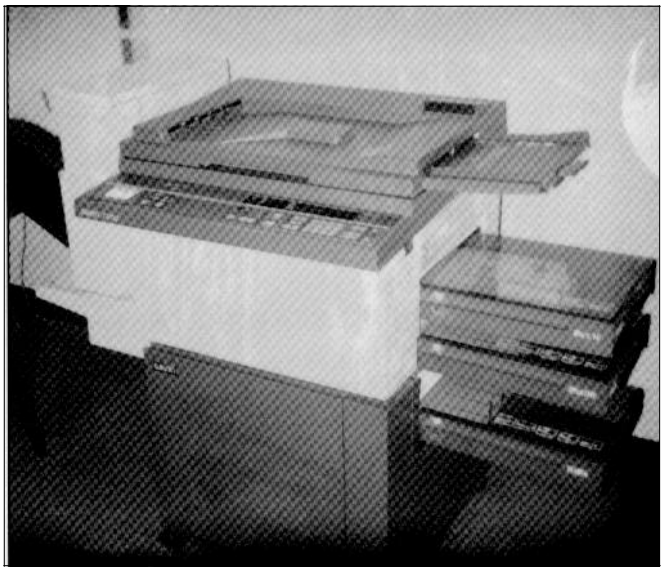
There are probably several thousand chemicals, synthetic and natural, that can be called volatile organic compounds or VOCs. All buildings contain a large variety of chemical sources, such as plastics, cigarette smoke, floor wax, furniture, building materials, and liquid process printers or copiers (see Figure 8). Some of the most commonly encountered ones and their sources are listed in Table 2.

The effects that each of these chemicals produce vary with the particular chemical. However, most chemicals will cause irritation if the concentrations in air are high enough. For instance, xylene is a VOC commonly found in paints and coatings. It can cause eye irritation at lower concentrations and act as a narcotic at higher concentrations. The way people respond to VOCs also depends on the individual. Use Table 2 and the location of complaints to identify the sources of VOCs that are likely to be causing your indoor air quality complaints.

Assessment

Inspections should be carried out in complaint areas and in locations that are potential sources of VOCs, such as print shops, photographic darkrooms, laboratories, and chemical storage areas. Although you would not normally apply indoor air quality standards to these industrial-type operations, they can act as a source of pollutants for other parts of the building.

Figure 8.
Liquid Process Copiers



The above photocopy machine is an example of a liquid process type copier. These types of copiers generally produce higher levels of VOCs than the dry process type of copiers. You can control the emissions of pollutants from this source by substituting machines or ensuring adequate ventilation.

When assessing the level of VOC contamination, you should try to find out if:

- the building is less than a year old,
- any area has been renovated or redecorated recently,
- any new furniture has been received within the past month,
- the cleaning products being used contain organic compounds that may evaporate into the air,
- cleaning is carried out at a time when few occupants would be present,
- extra ventilation or a separate ventilation system is being used in areas where large amounts of VOCs are being used (e.g., laboratories, copy rooms, photographic darkrooms), and
- there have been any new sources of VOCs (see Table 2) introduced to the building within the last year.

Table 2.
Commonly Encountered VOCs and Their Sources

Chemical	Source
Acetone	Paint, coatings, finishers, paint remover and thinner, and caulking
Aliphatic hydrocarbons (octane, decane, undecane hexane, isodecane, mixtures etc.	Paint, adhesive, gasoline, combustion sources liquid process photocopier, carpet, linoleum, caulking compound
Aromatic hydrocarbons (toluene, xylenes, ethylbenzene, benzene)	Combustion sources, paint, adhesive, gasoline, linoleum, wall coating
Chlorinated solvents (dichloromethane or methylene chloride, trichloroethane)	Upholstery and carpet cleaner or protector, paint, paint remover, laquers, solvents, correction fluid, dry-cleaned clothes
n-Butyl acetate	Acoustic ceiling tile, linoleum, caulking compound
Dichlorobenzene	Carpet, moth crystals, air fresheners
4-Phenylcyclohexene (4-pc)	Carpet, paint
Terpenes (Limonene, α-pinene)	Deodorizers, cleaning agents, polishes, fabrics, fabric softener, cigarettes

Solutions

Chemical emissions resulting from occupant or maintenance activities should also be addressed. You can:

- Increase the amount of outside air supplied to dilute concentrations if the source is weak (e.g., emissions from new furnishings).
- Store paints, cleaners, and solvents in areas with separate exhaust and not in fan rooms and air handling chambers.
- Choose dry copiers over wet copiers if many copiers are used in the building (see Figure 8).
- Install local exhaust for print machines, photographic darkrooms, and blueprinters.

C8. Micro-organisms

Many micro-organisms, such as fungi (moulds, yeasts), bacteria, viruses, amoebae, and nematodes, can be found in the indoor environment. Contamination of indoor air is often the result of a fault in the building's HVAC system or maintenance procedures. In these cases, the micro-organism is provided with conditions that allow it to grow and proliferate. Water spray humidifiers, reservoirs containing stagnant water, filters packed with organic dusts, and building areas that have been damaged by moisture all provide conditions that promote the growth of micro-organisms.

Viruses and bacteria are both common types of micro-organisms that can cause diseases. Viruses do not survive long outside the infected host, and transmission depends on contact with an infected individual. Because direct contact is required for transmission of viral infections, such infections are not usually related to indoor air complaints. Other micro- organisms can, however, be transmitted in airborne particles. *Legionella* and related species are examples of types of bacteria that can lead to disease. Legionnaire's disease is an infection that can lead to pneumonia in humans. Cooling towers, evaporative condensers, and hot water systems can be growth and distribution sites for *Legionella.*

Long-time exposure to most fungi can also induce allergic reactions in people. For instance, the inhalation of very large concentrations of fungal spores has been known to cause an allergic reaction called hypersensitivity pneumonitis. Because allergic reactions depend on how the exposed individual reacts, some people may be more susceptible to micro-organism exposures. These types of health problems are often difficult to diagnose with current medical procedures.

Because micro-organisms have the potential to cause serious health effects, all possible growth sites should be inspected and cleaned on a regular basis.

Assessment

All possible locations of micro-organism growth should be inspected, including:

- air intakes, filter units, cooling/heating fans and coils, spray humidifiers, reservoirs, ducts, insulation, air handling units, induction and fan coil units, drain and condensate pans, sumps, ceilings, and walls and carpets that are either dirty or wet,
- areas of mouldy damp odours and areas showing evidence of a previous flood or water leak,
- portable humidifiers and water coolers containing slime or algae, and
- mouldy ceiling tiles, plaster/gyprock, carpet, and window sills/frames.

Figure 9.
Personal Portable Humidifiers

Portable humidifiers that have been neglected are a common source of microbial growth and distribution. You should try to discourage the use of these units or at least ensure that they are cleaned on a regular basis.

Solutions

The principal guideline for microbial control is to keep fungal growth in buildings to a minimum. This can be accomplished in many ways:

- Remove water sources that encourage fungal growth. Prevent the accumulation of stagnant water in and around HVAC system mechanical components, such as under the cooling coils of air handling units.
- Repair all external and internal leaks promptly and permanently.
- Remove and discard porous materials that are contaminated (e.g., mouldy ceiling tiles, mildewed carpets, HVAC insulation).
- Disinfect* all smooth surfaces that have been contaminated by fungi.
- Use steam for humidification in HVAC systems rather than recirculated water, where feasible.
- If water sprays, wicks, or heated water tanks are used, a rigorous preventive maintenance program must be employed, as recirculated water systems can easily become contaminated with bacteria and fungi.
- Humidifiers should be drained and cleaned with a disinfectant* at intervals of two to four months.
- Rust and scale deposits should be removed from HVAC system components once or twice a year. HVAC systems should be turned off during cleaning operations, which should be scheduled during weekends and unoccupied periods.
- Personal portable humidifiers (see Figure 9) should be discouraged in offices. They are seldom maintained properly and can easily become contaminated. If they are the only solution for a humidity problem, it is important to ensure regular maintenance and cleaning.
- Use efficient filters to control the load of spores entering the air handling system.

* Use biocides, disinfectants, and sanitizers with caution. Some may themselves be the cause of a building's air quality complaints. Minimize occupant exposure by using these compounds outside of normal building hours and rinsing away any residue with large amounts of water.

Part 3:
Hiring a Consultant to Help

It is possible that, after completing the procedures outlined in Part 2 of this booklet, you have not yet resolved the indoor air quality complaints in your building. The next stage of the investigation will likely require a detailed evaluation of the performance of your building's HVAC system and measurements of air quality. This more detailed investigation involves the use of equipment and expertise not normally available to the general public. If this is the case, you will need to bring in some expert help to solve your indoor air quality problems.

As there are no legal restrictions on who can offer their services as an indoor air quality investigator, it will be up to you to ensure that they are qualified to do the work before you hire them. The following sections will help you find a competent consultant.

A. Where Do You Look?

There are several sources one can check for information and the names of consultants available locally. Governmental occupational health and safety regulators may be able to provide a list of consultants in your area. Other sources of information are the professional associations and public service organizations related to occupational safety and health. For instance, the Canadian Registration Board of Occupational Hygienists, the American Industrial Hygiene Association, and your provincial professional engineering association all have lists of members who provide consultant services. Another useful source can be the Yellow Pages of your phone book. Finally, there may be a university, college, or hospital in your area that has an occupational or environmental health program. Their staff professionals are often available for consultation.

B. Evaluating a Consultant's Qualifications

Once you find a consultant who claims to be able to perform an indoor air quality assessment, you will need to evaluate his or her qualifications. The best protection against an incompetent consultant is to question the prospective consultant yourself. A series of questions is given below. They should not be given equal weight, as some are minor in importance. (The list is organized roughly in descending order of importance.)

1. For how many years have you been professionally active in indoor air quality investigations?
2. Please supply a list of recent clients for whom you have performed indoor air quality investigations. (Be sure to call a few of these references to obtain their opinion on the consultant's services.)
3. Have you carried out this work on a full-time or part-time basis? If part-time:
   a. Who is your chief employer, or in what other business ventures are you involved?
   b. May we contact your employer concerning you?
   c. What restrictions does your employer place on you as a part-time consultant?
4. Are you associated with the manufacture or sale of a product that could create a conflict of interest in your activities as a consultant?
5. What degrees or diplomas have you received and when? (Preferably the consultant's educational background will be in occupational hygiene or mechanical engineering.)
6. What special conferences, seminars, symposia, or short courses have you attended (especially recently) to stay up to date with current developments in indoor air quality investigations?
7. What professional associations do you belong to? What is your present grade of membership and length of time in that grade for each association?
8. Are you certified or registered by any of the following?
   a. Canadian Registration Board of Occupational Hygienists
   b. American Board of Industrial Hygiene (specify area of certification)

c. Environmental Engineering Intersociety Board (as an occupational hygiene engineer)

d. the provincial professional engineering association

9. What equipment do you have for conducting indoor air quality investigations?
10. What laboratories do you use for the analysis of your exposure measurement samples? Are they accredited by the American Industrial Hygiene Association? Do they participate in the National Institute for Occupational Safety and Health (NIOSH) Proficiency Analytical Testing (PAT) Program and for what materials? (The American Industrial Hygiene Association journal periodically publishes a list of accredited laboratories.)
11. Can you refer me to engineering firms capable of installing controls such as local exhaust ventilation systems if these are necessary? Do you have any business connection with these firms?
12. Please indicate your fee structure. Do you work by hourly charges, estimates for the total job, retainer charges, or any of these?
13. In your charges, how do you treat such expenses as travel, subsistence, shipping, report reproduction, and computer time?
14. Can you supply a list of typical laboratory analytical fees?
15. What insurance and bonding do you have?
16. What restrictions are there on the use of your name in our reports or in litigation?
17. What are the character and extent of reports that you prepare? Can you supply an example?
18. What is the size of your staff? What are their qualifications? Who will be working on this project?

C. Defining the Work to Be Completed

Once you have found one or more consultants who can do the work, you will need to define the type of work to be completed. One of the best tools to accomplish this task is to have the consultants prepare a project proposal for your review.

Often, in a larger job, proposals from several points of view are evaluated and used as one of the bases for the final selection of the consultant. In this case, answers to pertinent questions in the preceding section may be sought in the proposal rather than in the interview.

Aside from background qualifications of the consultant, the proposal should answer the following questions:

1. How much is the service going to cost? Smaller jobs are often bid on an hourly basis, typically with a minimum of one-half day's work, plus direct expenses commonly specified. Larger jobs are usually bid at a fixed amount, based on the work steps described.
2. What is the consultant going to do? The answer to this question may range all the way from a simple agreement to study the problem to a comprehensive step-by-step plan to solve it.
3. What will be the end result? The answer to this question is all too often not clearly understood; the result is usually a report that specifies the consultant's recommendation. If you do not want to pay for the preparation of a written report, and a verbal one will do, specify this in advance. As recommendations often call for construction to be carried out by others whose work is not subject to the consultant's control, results usually cannot be guaranteed. Rather, an estimate of the results to be attained is all that can be expected.

Appendix A:
Government Agencies

A1. Provincial and Territorial Agencies

Alberta Occupational Health and Safety
4th Floor, Donsdale Place
10709 Jasper Avenue
Edmonton, Alberta
T5J 3N3

Division of Environmental Health
Department of Health and Social Services
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8

Health and Safety Department
Nova Scotia Department of Labour
P.O. Box 697
5151 Terminal Road, 6th Floor
Halifax, Nova Scotia
B3J 2T8

Health and Safety Support Services Branch
Ministry of Labour
400 University Avenue
7th Floor
Toronto, Ontario
M7A 1T7

Institut de recherche en santé et en
sécurité du travail
505, boulevard de Maisonneuve Ouest
Montréal, Québec
H3A 3C2

Manitoba Department of Labour
Workplace Safety and Health Branch
1000 – 330 St. Mary's Avenue
Winnipeg, Manitoba
R3C 3Z5

Occupational Health and Safety Branch
Saskatchewan Department of Labour
1870 Albert Street
Regina, Saskatchewan
S4P 3V7

Public Health Protection Branch
Ministry of Health
1515 Blanchard Street
Victoria, British Columbia
V8W 3C8

Safety and Public Services
Government of the Northwest Territories
P.O. Box 1320
Yellowknife, Northwest Territories
X1A 2L9

A2. Federal Agencies

Buildings Group
Energy Efficiency Division
Natural Resources Canada
580 Booth Street
Ottawa, Ontario
K1A 0E4

Building Performance Division
Public Works and Government Services Canada
Sir Charles Tupper Building
Confederation Heights
Riverside Drive
Ottawa, Ontario
K1A 0M2

Environmental Health Directorate
Health Protection Branch
Health Canada
Environmental Health Centre
Tunney's Pasture
Ottawa, Ontario
K1A 0L2

Occupational and Environmental Health Directorate
Medical Services Branch
Health Canada
Jeanne Mance Building
Tunney's Pasture
Ottawa, Ontario
K1A 0L3

Research Division
Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

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