VENTILATION IN OCCUPIED BUILDINGS

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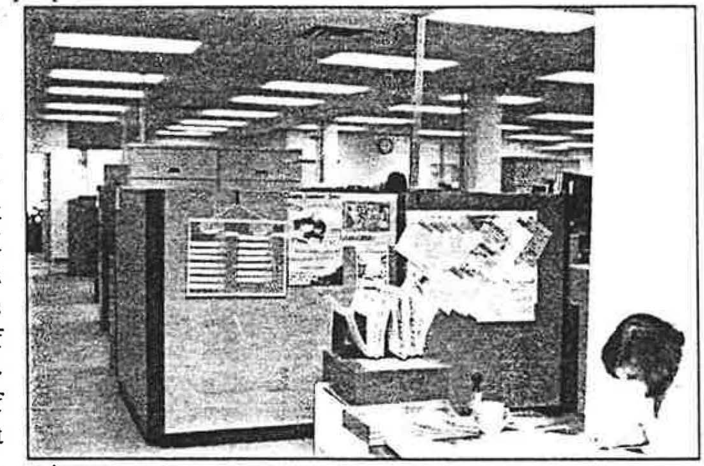
INTRODUCTION

Occupied buildings are designed to provide safe, comfortable environments for people to live and work. Within this statement, the terms safe and comfortable must be applied to two types of occupants; the general population and specific individuals. Thus, what may be considered safe and comfortable (acceptable) to most people may not be acceptable to specificindividuals.



In an attempt to define acceptableenvironments, regulations, standards or guidelines for specific environmental factors (light levels, noise, ventilation and someair pollutants) have been developed by various agencies.The underlying focus of these agencies has been to minimize the negative health effects of exposure while recognizing that there are economic limits to most situations. If the standard is generated by a public health agency, effects on occupant productivity and perceived comfort may be of less concern than documented health risks. Therefore, in addition to the variation in individual responses and perceptions, the economic relationships among owners/employers/occupants must be considered. Many standards have established maximum permissible levels based on health risk plus recommendations for enhanced environmental conditions which will increase the number of people who consider the environment acceptable.

It is generally recognized that a supply of ventilation air outdoor air or indoor air that has been treated to maintain acceptable indoor air quality) is a basic requirement for occupied buildings. Some design standards (1,2,3) require specific amounts of ventilation to be supplied to buildings, others require certain indoor pollutant concentrations to be controlled to specified levels (4,5,6).

The purpose of this report is to outline the role of ventilation in controlling indoor pollutant concentrations in buildings and discuss general strategies for providing adequate ventilation. Since the treatment or cleaning of indoor air is a complex and relatively uncommon practice in Canada, this report will deal with ventilation using outdoor air.

ROLE OF VENTILATION IN POLLUTANT CONTROL

Ventilation is only one component of the heating, ventilating and air conditioning (HVAC) system of a building. Most HVAC systems supply air to a space through grills or diffusers. The supply air is a mixture of outdoor air plus room air (return air) that is recirculated. Since outdoor air is being added to the system, some provision must be made to exhaust air from the building. This exhaust may occur through leaks in the building envelope or may be vented outdoors with fans. Heat may be extracted from the warm exhaust air stream and reused in the HVAC system.

Within the HVAC system, the various air flows may be heated, cooled, cleaned or conditioned in various ways.

To understand the function (and limitations) of ventilation as a means of controlling indoor pollutant concentrations, the relationship between the major factors that influence indoor pollutant levels must be developed. A thorough development of this procedure is given in Ref. 1. In the simplified case of a building with one open area and with well mixed air:

$$Ci = Co + N/V \quad (1)$$

where:
Ci = indoor pollutant concentration ($\mu g/m^3$)
Co = outdoor pollutant concentration ($\mu g/m^3$)
N = indoor pollutant generation rate ($\mu g/m^3$)
V = ventilation rate (m^3/h)

Although this is a simplified model of a real environment, it shows that indoor pollutant concentrations are related to three major variables: the outdoor pollutant concentration, the indoor pollutant generation rate and the ventilation rate. When a pollutant is present in the outdoor air, the effectiveness of the ventilation is reduced since it will carry some of the pollutant indoors. Variations with time of any of the factors will result in a change in the indoor concentration.

This model also indicates potential control methods for indoor pollutants. Halving the strength of the indoor pollutant source will have the same effect as doubling the ventilation rate. It is very important to identify the origin of pollutant emissions to ensure that an appropriate control method is selected.

Equation 1 assumes well mixed air. It does not, therefore, highlight the fact that in order for the ventilation to be effective in diluting the indoor pollutants, it must be distributed to the areas where pollutants are being generated.

METHODS OF PROVIDING VENTILATION

There are two basic methods used for supplying ventilation to buildings:

a) Natural Ventilation

Natural ventilation is supplied by air leakage into and out of the building enclosure, either through unintentionally created openings in the building (infiltration) or through intentional openings such as windows, doors and louvres. During winter, cold drafts may exist at places where the outdoor air enters the building while outgoing air can deposit moisture in the building envelope. The flow of air is governed by the size and location of the openings, occupant activities and wind and temperature forces. As a result, the air flow rate is uncontrolled and highly variable. At times the rate may be excessive (wasting heating or cooling energy) or insufficient (resulting in elevated indoor pollutant concentrations). It is also difficult to ensure that the ventilation is distributed to the proper areas of the building.

b) Mechanical Ventilation

Mechanical ventilation is supplied by a mechanical system, usually including fans and a ductwork system for distributing the air throughout a building. The system may also include equipment for controlling humidity, heating or cooling and air cleaning. This type of system can provide a controlled flow of conditioned air to all areas of a building. Control systems (thermostats, humidistats, timers) are normally installed on mechanical systems to regulate their operation and adjust the flows to control indoor temperatures or conserve energy when possible. Problems can occur when the control system does not respond to the indoor pollutant sources. This situation can result from improper design, maintenance deficiencies or changes in building operation or occupancy that were not anticipated in the original design. One example of this type of problem is variable air volume (VAV) systems in large buildings. The amount of air supplied to a space is regulated by the heating or cooling requirement (thermostat) and unless an acceptable minimum flow is provided, indoor pollutant problems can occur even though thermal conditions are acceptable. A parallel problem can occur in homes with fresh air intake ducts connected to the furnace return air ductwork. Ventilation is only actively supplied to and distributed within the building when the furnace fan is operating.

Non-residential buildings are usually ventilated by mechanical systems. Tightly sealed residences can not rely on natural ventilation to supply sufficient quantities of ventilation to all areas. Problems have occurred in defining criteria for deciding whether a building needs a mechanical ventilation system or whether the natural ventilation will be sufficient. Unfortunately, for many houses, some combination of the two methods is necessary. As the building envelope is made tighter (careful new house construction or retrofitting of an existing house) a smaller fraction of the total ventilation requirement can be reliably supplied by natural ventilation. In the case of some houses, air tightening measures were used to reduce infiltration without consideration of the effect on indoor air pollutant concentrations.

Since the total ventilation requirement is controlled by the indoor pollutant sources, as natural ventilation quantities are reduced, mechanical ventilation quantities must be increased unless pollutant sources are reduced accordingly.

POLLUTANT SOURCES

Pollutant sources must be clearly identified as originating from outdoors or indoors since strategies for controlling the resulting indoor pollutant levels will be quite different.

Outdoor pollutants can include widespread, constantly elevated levels of pollutants (eg. industrial emissions) or specific intermittent sources such as delivery vehicle exhaust fumes entering ventilation air intakes. Dust, pollen and other allergens are also common outdoor pollutants.

Indoor pollutant sources can be broadly categorized as occupant related and non-occupant related sources.

a) Occupant related sources

Indoor pollutants related to occupancy encompasses a wide spectrum ranging from; emissions from the human body (CO_2, water vapour, bacteria and viruses or chemicals from other metabolic processes) to emissions from human activities (smoking, perfumes, cleaning chemicals, photocopier emissions, clothing). Typically, these sources vary widely on a hourly and daily basis. Ventilation systems must be capable of diluting all of these highly variable "uncontrolled" sources to ensure acceptable levels.

b) Non-occupant related sources

This category includes emissions from building materials and interior furnishing (formaldehyde, volatile organic compounds, asbestos and other particulates), indoor combustion sources (CO_2, NO_x, CO) and a wide variety of other specific products. These sources can vary over a short (hourly or daily) or long (yearly) term.

In some cases, data on the strength ofpollutant sources is available but more often, the system designer must estimate the sources based on experience alone. New buildings may have an initially high rate of offgassing of chemicals from the building materials which will decrease with time.

VENTILATION SYSTEM DESIGN

The ventilation system designer must select a system which will provide adequate ventilation for a potentially endless, undefined mixture of pollutants. The system must be cost effective which often means energy efficient, comfortable and flexible enough to accommodate future changes.

Ventilation codes and recommendations have been developed based on some typical pollutant sources to give designers guidance for selecting reasonable ventilation rates. Individual circumstances must be reviewed to ensure that other special pollutant sources do not exist. In special situations, the pollutant mass balance model (equation 1) must be used.

Ventilation for diluting internally generated pollutants should be used as a supplement to good engineering practice, rather than a cure for all indoor air quality problems. Often, removing a pollutant source or isolating it from the main occupied space is more appropriate than allowing it to escape into the air and controlling the concentration by dilution.

In general, the key elements to proper ventilation system design include:

1) Continuous Supply

Since indoor pollutant sources include continuous and variable sources, if maximum indoor pollutant concentrations are to be controlled without "over ventilating", the ventilation system must supply a basic minimum flow of air continuously as well as being able to increase the air flow to compensate for increased pollutant emissions. Universal sensors for detecting all forms of "unacceptable" indoor air quality to not exist. The system designer must, therefore, arbitrarily select a control criteria. Manual switching, programmable timers and temperature, humidity or CO_2 sensors are some methods used to try and reduce mechanical ventilation when possible. Infiltration cannot provide reliable ventilation for pollutant control. Natural ventilation is normally controlled by individuals who open and close windows based on their perception of comfort. These changes can have major effects on the ventilation and pollutant concentrations in other areas of the building.

Control strategies should be developed from a thorough understanding of the construction and operation of the building. Occupant behaviour, floorplans, time dependent characteristics of the potential pollutant sources and use schedules must be developed and evaluated.

2) Distribution and flow

Proper air distribution is required to ensure that stale or "dead" areas in the building do not exist. The selection and placement of supply air diffusers and return air grilles can have a major impact on the effectiveness of the ventilation to control pollutant concentrations. Changes in interior floorplan and architectural layout can also affect air distribution.

Since the ventilation air is supplied in a relatively "clean" state and increases in pollutant concentration as it moves through the building to the return air system, the location of supply and return air grilles relative to the occupants can minimize the exposure to the more contaminated portions of the room air.

3) Provision for maintenance and adjustment

All mechanical equipment is subject to wear and neglect. Air cleaning and humidifying equipment, drive belts, fans and dampers will require cleaning and adjustment to ensure their proper performance. New mechanical systems must be thoroughly checked for proper operation and the owner/operator must be instructed as to the purpose and maintenance needs of the system components.

4) Relative humidity control

During cold winter conditions, interior relative humidity levels can become excessive. Condensation can occur on windows, areas that are poorly insulated and areas that become cold due to inadequate air circulation. Reducing the set point temperature of heating thermostats (eg. night setback) can aggravate the condensation problem since surface temperatures (especially exterior walls and windows) will drop and fan operation (air circulation) may be interrupted. Condensation can cause problems with appearance (staining), increased heat loss (wet insulation), building deterioration (wood rot) and can also provide conditions favourable to the growth of microbiological contaminants such as moulds and fungi.

Table 1 suggests a broad rance of acceptable indoor relative humidity levels based on health criteria. The upper values highlight the importance of not raising humidity levels beyond those which can be tolerated by the building.

5) Interaction with other building activities

HVAC systems can affect or be affected by other processes within a building. Pressure difference within a building caused by wind or temperature forces (stack effect) or by mechanical equipment can affect the strength or distribution of indoor pollutant sources.

Chimney backdrafting (entry of combustion by-products) can occur when the negative pressure in a building interferes with the proper operation of a chimney. The rate of radon gas entry from the soil into a building foundation may also be increased when the below grade portion of a building is under a negative pressure.

The effect of any modification to a building should be carefully evaluated to assess it's potential impact on the indoor environment.

Shaw (7) present some useful design considerations for residential ventilation systems.

CODES AND GUIDELINES

Ventilation standards that specify air flow rates are often based on past experience with buildings that did not exhibit problems with indoor air quality or are selected to control specific air pollutants such as carbon dioxide emissions from building occupants. These standards recognize that the list of potential pollutants is endless and that often, detailed information n pollutant sources is not available. Since buildings must continue to be built, these standards provide a basic starting point for designers. Some commonly referenced ventilation standards are summarized in Table 2.

Permissible levels of specified air pollutants for Canadian occupational exposures are given in documents such as Ref. 5 published by provincial departments of labour.

Until recently, Canada did not have specific guidelines for indoor pollutant levels in residences. In 1987, Health and Welfare Canada established guidelines for some common residential indoor air pollutants (4). These guidelines are summarized in Table 1.

Standards that specify maximum pollutant concentration levels require the building designer to have information about the strength of all of the potential indoor pollutant sources. In practical terms, it may not be possible for the designer to identify the pollutant source that dictates the highest required ventilation rate or to anticipate all possible future changes in indoor conditions.

Today, "good engineering practice" requires a designer to incorporate the best of both approaches. Ventilation standards should be considered as a baseline and known indoor pollutants should be checked to ensure that the maximum allowable concentration levels are not exceeded.

CONCLUSIONS

The proper design of systems to control indoor pollutants requirers a thorough understanding of the basics of HVAC engineering and industrial hygiene. In many "typical" circumstances, rules of thumb and conventional system design may provide adequate results. Often, however, problems occur, not as a result of some unusual pollutant problem, but because the basic system design or operation is inadequate.

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Table 1. Residential Pollutant Exposure Guidelines (Ref.4)

POLLUTANT	GUIDELINE LEVEL Acceptable long-term exposure (Acceptable short-term exposure)
Formaldehyde	0.1 ppm action level (0.05 ppm target)
Carbon Monoxide	11.0 ppm (25.0 ppm)
Carbon Dioxide	3500 ppm
Nitrogen Dioxide	0.052 ppm (0.25 ppm)
Ozone	— (0.12 ppm)
Particulate Matter	40 µg/m³ (100 µg/m³)
Sulphur Dioxide	0.019 ppm (0.38 ppm)
Water Vapour	30% - 80% RH summer 30% - 55% RH winter
Biological Agents Consumer Products Fibrous Materials Lead Polycyclic Aromatic Hydrocarbons Tobacco Smoke	Eliminate or minimize exposure

Table 2. Ventilation Standards and Guidelines

Standard or Guideline	Ventilation Requirement Continuous (C) Intermittent (I)
ASHRAE 62-81	5 L/s per room - bedrooms, living areas and all other rooms (c) 50 L/s per room - kitchen (I) 25 L/s per room - bathrooms (I)
1985 National Building Code of Canada	0.5 air changes/h installed capacity (I)
EMR R-2000 Design Requirements	5 L/s per room - bedrooms, living areas kitchens & bathroom (C) 10 L/s per room - basements, utility areas (C)

EMPLOYMENT OPPORTUNITIES

Applications are being accepted for the position of Certified Public Health Inspector with the Kingston,Frontenac and Lennox and Addington Health Unit. The successful candidate will work out of the Kingston Office. The position involves conducting a generalized inspection program including responsibilities for private sewage systems under the Environmental Protection Act.

Salary range is $28,960 - $35,346 and start rate will be commensurate with qualifications and experience. An excellent benefit package is offered.

The successful applicant must provide and operate a vehicle, for which an allowance is paid.

Written applications, complete with resume, should be forwarded to:

Personnel, Kingston, Frontenac and Lennox
and Addington Health Unit,
221 Portsmouth Avenue,
Kingston, Ontario K7M 1V5

The Public Health Inspection Department of the Timiskaming Health Unit requires one full time staff Public Health Inspector in our Kirkland Lake office. This position is generalized and includes a land control program.

Our 1988 salary range is $28,043 to $33,671 (currently under review). A reliable vehicle is required with transportation allowance at $50.00 per month plus .24 per kilometre, usual fringe package.

Enquiries or applications complete with resume and reference are to be forwarded to:

R.E. Birch, C.P.H.I.(C)
Director of Public Health Inspection
Timiskaming Health Unit
P.O. Box 670
Englehart, Ontario P0J 1H0
Telephone: 705-544-2221

YUKON CAREER FAIR WHITEHORSE, YUKON

BY
Gordon William Allen, B.A., C.P.H.I.(C), C.H.S.P., C.O.H.S.T., C.S.T.

The Yukon Career Fair held at F. H. Collins High School was widely publicized resulting in a significant turn-out of interested local residents and students.

The main goal of course was to encourage students to think about careers and introduce students considering career choices to people already working in those areas who can provide them with current information.

The Environmental Health Division, Medical Services Branch, Health and Welfare Canada - Whitehorse gladly agreed to become a participant in the Career Fair. It gave us the opportunity to "blow our own horn" by informing students and adults alike what the nature of our work entails. We found our booth swamped with individuals who either knew the services our department provided or knew nothing about our department. Many students took a serious interest in our field of work and were interested in the details of entering the field.

The Career Fair was a true success from our standpoint, and we plan on being annual participants as it is one of the true means of meeting the public whom we serve in the Yukon.

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HVAC systems should be designed, installed and maintained by qualified professionals. Building operators and homeowners may have to hire an independent consultant or become technically competent to ensure that their HVAC system performs adequately. The impacts of changes to the building envelope, interior usage or HVAC system must be carefully evaluated.

For more information contact the authors FAX (306) 975-5956 or (306) 975-4200 or Technical Information Group, National Research Council of Canada, Institute for Research in Construction, Bldg. M-20, Ottawa, ON, K1A 0R6.

REFERENCES

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