

Ventilation of residential buildings: Impacts on the occupants' respiratory health¹

SUMMARY DOCUMENT

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INTRODUCTION

A residential building's indoor air can theoretically contain various types of contaminants to which the occupants could be exposed. Many studies have established links between the presence of indoor air contaminants and some health problems. A reduction in indoor air contamination must ideally be the subject of a strategy encompassing a certain number of measures, with control at source definitely being the first option to be considered. However, this approach alone is not sufficient to reduce all of the contaminants present, so other complementary measures need to be considered, such as the ventilation of indoor spaces.

¹ This document is a summary of the scientific report "La ventilation des bâtiments d'habitation : impacts sur la santé respiratoire des occupants," available on the Institut national de santé publique du Québec's Web site at: <http://www.inspq.qc.ca>. Any reader interested in obtaining more details about a particular section or in knowing the bibliographical references is invited to consult the main document.

At the present time, the application of regulations on the ventilation of small residential buildings varies greatly in Québec, with municipalities having the power to adopt their own construction regulation. The Régie du bâtiment du Québec (RBQ) wants to adopt a uniform basic standard for all new buildings, particularly concerning the installation of mechanical ventilation systems. However, the RBQ is running into some resistance, considering the technical, legal and socioeconomic difficulties that may arise from the application of such a measure. In addition, professionals from municipalities and the housing community, as well as consumers, are generally poorly informed about the actual ventilation issues pertaining to indoor air quality and the occupants' health.

To do so, we have reviewed the main technical and regulatory aspects relating to the ventilation of residential buildings and analyzed the scientific literature on the direct and indirect relationships between ventilation and the occupants' respiratory health. We then summarize our reflection on the quality of the scientific evidence, the applicability of the results to Québec, the application and determination of a minimum ventilation rate and, finally, on the factors likely to affect ventilation efficiency.

MAIN TECHNICAL ASPECTS RELATING TO THE VENTILATION OF RESIDENTIAL BUILDINGS

Ventilation is the process by which indoor air is replaced by the admission of fresh air and the exhaustion of stale air, by natural or mechanical means, in order to ensure the occupants' comfort. A

residential building's ventilation requirements depend on many factors, which can vary from one residence to another. The differences in temperature between the indoors and outdoors, wind, and the equipment that exhausts or introduces the air are some factors likely to have an impact on a residence's air pressure, a phenomenon associated with air movement indoors. Furthermore, the improvements to recent residential construction methods have made residences more airtight. As well, an increasing number of existing houses have been the subject of improvements in insulation, the installation of windows and doors with high energy efficiency, etc. In a great many of these houses, air infiltration through the doors and windows as well as through openings in the building envelope is generally no longer sufficient to provide appropriate and uniformly distributed ventilation in the habitable rooms of the house. Mechanical ventilation then becomes an additional means to be considered, particularly during the heating season. There are three main types of mechanical ventilation, namely exhaust only, supply only, and balanced. In apartment buildings, the typical installations are generally air supply systems in corridors, paired with exhaust fans in the apartments. A heat recovery ventilator (HRV) that provides balanced ventilation while recovering heat is the system currently referred to by experts and often recommended in the standards. Proper operation of a ventilation system, and as a result its efficiency in distributing the desired air flows, are the result of the design and selection of the type of system, its installation (including location and balancing), its maintenance and its use.

REGULATION APPLICABLE TO THE VENTILATION OF RESIDENTIAL BUILDINGS

The ventilation rates required for residential buildings are prescribed by standards that are managed to different extents and in a variable way. The ASHRAE *Ventilation for Acceptable Indoor Air Quality* standards are the best known and serve as a model code worldwide. In most countries, the ventilation rate required in residences is between 0.3 and 0.5 air changes per hour (ACH), with this latter rate being prescribed in the Scandinavian countries, among others. Since the early 1980's, North America has seen a downward trend in ventilation standards, likely due to concerns about energy conservation. In Canada, ventilation requirements are found in the National Building Code (NBC) in parts 6 *Heating, Ventilating and Air-Conditioning* and 9 *Housing and Small Buildings*. The NBC serves as the model building code, which has force of law when adopted by a province, territory or municipality. In the 1995 version of this code (version to which the Québec regulations currently refer), the ventilation rate necessary for an individual or autonomous installation is calculated on the basis of the number and types of rooms, and equals approximately 0.3 ACH. In Québec, these requirements are found in the first chapter of the Québec Building Act, a chapter basically developed from the NBC and some modifications intended to make it easier to apply and adapt to Québec's specific needs. Some buildings, such as small single-family type buildings, are currently not subject to this chapter of the Québec Building Act, and as a result, are generally under the jurisdiction of municipalities. However, the regulations adopted by municipalities on this subject

vary greatly, with some municipalities having adopted previous versions of the codes, modified or not, and others having adopted no construction code. This fact leads to regulatory diversity in the ventilation of small residential buildings.

EFFECTS OF RESIDENTIAL BUILDING VENTILATION ON THE OCCUPANTS' RESPIRATORY HEALTH

Current ventilation standards are not based on the prevention of health problems, but instead on the prevention of discomfort problems related to odours (bioeffluents). Over the last 20 years, several studies have been carried out around the world to evaluate the effects of ventilation on health. The main problems studied are acute respiratory and allergy symptoms, including asthma in particular. In some cases, researchers have studied the direct relationship between ventilation and respiratory health and, in other cases, the indirect relationships related to the effect of ventilation on three main groups of indoor contaminants, namely house dust mites (HDM), moulds and volatile organic compounds (VOCs), and more particularly formaldehyde. To measure the relationship between ventilation and respiratory health, researchers have compared the frequency of symptoms in relation to the presence of mechanical ventilation or natural ventilation and/or in relation to the ventilation rate measured in air changes per hour (ACH). Several studies have been carried out in public buildings and office buildings on the relationship between ventilation and tight building syndrome (TBS), which includes symptoms related to upper respiratory tract irritation. Also, in order to take into consideration all the available information,

we also reviewed the most recent knowledge on this subject. We identified all of the scientific publications relating to ventilation and respiratory health, in particular asthma symptoms, indexed in the MEDLINE and EMBASE electronic databanks, as well as the *Cochrane Library* and various documentation centres. After a review and analysis, we retained 75 residential building studies published over the last ten years. We also analyzed 13 studies carried out in public buildings and office buildings. Using the methodological approach developed by the Canadian Task Force on Preventive Health Care, we classified and analyzed the studies according to the hierarchy of studies based on the level of evidence: randomized trial, non-randomized trial, cohort, control cases, descriptive studies, and expert opinions.

The direct relationship between ventilation and respiratory health

The review on the direct relationship between ventilation and health is based on 13 studies conducted in residences. These studies were grouped as follows: 3 intervention studies, 6 cohort/control case studies, 3 descriptive studies, and 1 review. Ten (10) of these studies were carried out in Scandinavia. Twelve (12) studies produced conclusive effects, 8 of which showed significant results, and 4 showed the absence of any effect. Several quality studies suggest that there is a direct link between ventilation and an improvement in respiratory health in asthmatics and in the general population. In adult asthmatics, Harving *et al* (1994a) showed in a quasi-experimental study that mechanical ventilation had a significant sustainable positive impact on the forced expiratory volume/second (FEV₁), peak flow rate, antibody level, symptoms, and the consumption of

medication. The intervention study carried out by Leech *et al* (2004), in Canada, showed a statistically significant improvement in respiratory symptoms in the general population related to the installation of mechanical ventilation in R-2000 homes. The quasi-experimental study by Engvall *et al* (2005) on healthy adults, even though it revealed a positive impact of the ventilation rate on odour perception and indoor air quality, did not show any effects on respiratory symptoms. We should emphasize that the symptoms were measured using a questionnaire on TBS and not a standardized respiratory questionnaire. The cohort/control case studies show that the presence of mechanical ventilation reduces the risk of symptoms by 8 to 72% in the occupants. The presence of natural ventilation is associated in one study with a three times higher risk of wheezing. Finally, one study showed that a ventilation rate below 0.5 ACH together with excessive humidity was associated with a risk of bronchitis close to 10 times higher in the occupants. The recent study by Bornehag *et al* (2005) revealed a statistically significant association between the ventilation rate and the symptoms of asthma and allergy in children.

The indirect relationships between ventilation and respiratory health

Relationship to house dust mites (HDM)

Our analysis involved 27 studies (4 HDM/health, 23 ventilation/HDM) on indirect ventilation/humidity/mite/respiratory health relationships. Of these studies, there were 10 intervention studies including 1 randomized study, 2 cohort/control case type studies, 8 descriptive studies and 7 reviews. Seven (7) studies were conducted in Scandinavia, 5 in Great Britain (solely intervention studies) and 5 in North

America. Twenty-two (22) studies were conclusive. Three (3) studies were negative, including 2 intervention studies. Overall, these studies, which were the subject of several reviews, showed an association between mite exposure in the home and sensitization to mite allergens, the “development” of asthma in children, as well as the exacerbation of asthma in sensitized individuals. Based on the criteria of Bradford-Hill, the IOM concluded that it was a causal relationship. We should also point out that some researchers, such as Pearce *et al* (2000), believe that, considering the uncertainty surrounding the diagnosis of asthma in young children, the relationship to the development of asthma is less certain. However, these authors do not question the relationship between HDM exposure and an increased frequency of respiratory symptoms in children and the exacerbation of asthma in sensitized individuals.

Several intervention studies have been carried out to evaluate the capacity of mechanical ventilation to reduce the indoor humidity level, the number of mites, and the concentration of allergens in dust, as well as, in some cases, the frequency of respiratory symptoms. The results of several studies conducted in Scandinavia have shown a positive impact of ventilation on the three environmental parameters, one of which included an improvement in respiratory symptoms. The intervention studies carried out elsewhere in the world (Great Britain, Australia, North America) were in general negative regarding the impact on occupants’ respiratory health. However, several of them indicated that ventilation reduced indoor humidity. A few also showed a reduction in HDM and allergens, namely the studies in North America on conditioned air. In general, the results of the studies conducted outside Scandinavia

showed a more mitigated impact, which can possibly be explained by the climatic differences and the small number of studies undertaken. Korsgaard (1998b) emphasized the vital importance of residential ventilation in controlling the proliferation of HDM by using mainly the three Scandinavian studies of Munir *et al* (1995), Harving *et al* (1993) and Sundell *et al* (1995) as a basis. This researcher recommends maintaining indoor humidity below 7 g/kg or 45% for a few months of the winter. A mathematical formula is used to determine the minimum air change rate per hour according to geographical region, by taking into account the outdoor humidity during the winter, the surface area of the dwelling, and the number of occupants (Korsgaard, 1998a).

Relationship to moulds

We analyzed 19 studies dealing with ventilation/humidity/mould/respiratory health relationships. We found no intervention study. The studies were grouped as follows: 4 cohort/control case type studies, 10 descriptive studies, and 5 reviews. Seven (7) studies were inconclusive. Of the 12 other studies, 11 showed significant effects, characterized mainly by a relationship between exposure and a higher frequency of asthma-related symptoms in children. Two new recently published cohort studies on children revealed a statistically significant relationship between exposure to moulds and an excessive risk of “developing” asthma and of presenting respiratory symptoms, particularly if the parents are atopic. A descriptive study carried out on asthmatic adults showed an increase in symptoms associated with exposure to moulds. The only published studies on the impact of ventilation on indoor mould concentration were descriptive studies. The results of these latter studies suggest

that a lack of ventilation (in this case, natural ventilation by the windows) tends to result in an increase in spore concentrations in the air.

Relationship to volatile organic compounds (VOCs)

Studies on the relationship between residential exposure to VOCs and respiratory health are few. We analyzed 16 studies grouped as follows: 4 intervention studies, 4 cohort/control case studies, 4 descriptive studies and 4 reviews. Five (5) of the 16 studies were inconclusive. Eight (8) of the 11 remaining studies showed statistically significant effects characterized by an increase in the frequency of asthma symptoms in children exposed to VOCs and in respiratory symptoms in healthy adults. The review of Dales and Raizenne, published in 2004, documented some twelve studies to which were added 2 more recent control case studies. While the older studies used an exposure measurement based mainly on a questionnaire and observation of the premises in order to identify the presence of emission sources (wallpaper, rugs, etc.), the studies of Rumchev *et al* (2004) and Venn *et al* (2003) used measurements of VOC concentrations in the air. These two studies showed a statistically significant relationship between VOC exposure and excessive respiratory symptoms.

Regarding the effect of ventilation on indoor VOC concentrations, it is possible to estimate from the work of Sherman and Hodgson in 2004 and the work of an *Institute of Medicine* Committee in 2000, and based on mathematical models, the expected impact on air quality and respiratory health. These models estimate the effect of ventilation on the concentrations of certain types of contaminants, which depends to a large extent on particle size.

Therefore, the ventilation rate has little impact on the concentrations of large particles, such as those associated with mites, cockroaches and spores. However, a change in ventilation rate has a major impact on the concentrations of small particles such as those found in tobacco smoke and cat allergens. In fact, the concentrations of these types of contaminants may increase very significantly if the ventilation rate is below 0.25 ACH, for example. The ventilation rate has little effect on the concentrations of gaseous contaminants, particularly if they are less volatile. However, in Quebec City, Canada, the results of a recent study published by Gilbert *et al* in 2006 have shown that formaldehyde concentrations in a sample of homes are negatively correlated with air change rates. In brief, the results of the studies suggest that the ventilation rate mainly affects exposure to tobacco smoke, cat allergens, infectious bioaerosols, and some VOCs.

Studies carried out in public buildings and office buildings

The results of the ventilation studies carried out in schools and office buildings seemed relevant to us, mainly for comparisons between natural ventilation and mechanical ventilation, as well as the ventilation rates. However, unlike residential buildings, these environments are generally equipped with a more complex system that combines heating, ventilation and air conditioning. Care must therefore be taken in comparing the results of studies carried out in public buildings and office buildings with those of studies carried out in residences, considering the differences in the components of these systems. Furthermore, the studies carried out in workplaces do not specifically address respiratory symptoms and asthma.

Overall, for public buildings and office buildings, we documented and analyzed 13 studies involving ventilation and tight building syndrome (TBS). The studies were grouped as follows: 3 intervention studies, 3 descriptive studies and 7 reviews. Most of these studies were conducted in Scandinavia and in North America. Of the 11 conclusive studies, 9 showed statistically significant effects associated with mechanical ventilation. In these buildings, the results demonstrate that the risk of TBS-related symptoms increases 3 to 6 times in the presence of mechanical ventilation as compared to natural ventilation. We should point out, however, that the studies of Mendell *et al* (1996) and Seppänen and Fisk (2004) showed that the risk of respiratory problems was significantly higher in buildings with a system combining heating, ventilation and air conditioning (HVAC), suggesting a higher risk of biological contamination with this type of system. Moreover, the results of the studies show that an increase in the ventilation rate significantly decreases the frequency of these symptoms (from 20% to 40%) and sick leave (50%).

Preventive measures based on the weight of the evidence

We used the criteria developed for the recommendations of the Canadian Task Force on the Periodic Health Examination to identify the preventive measures related to ventilation, the expected impacts, the level of evidence about these impacts, and the appropriate recommendations based on the level of evidence. The classification of evidence levels and recommendation grades, or A (*good*), B (*fair*) and C (*weak*), provides foundations for recommendations applicable to residential building ventilation.

We identified two preventive measures to which recommendations on residential buildings can refer: the installation of a mechanical ventilation system or not, and the determination of a minimum ventilation rate. We also identified the direct and indirect impacts of these two measures, based on the scientific literature. The recommendation grades are based on the type of studies published. For mechanical ventilation in residential buildings, the evidence of a beneficial effect on respiratory health, whether direct or indirect due to mites, is moderate and supports a class B recommendation. Regarding moulds and VOCs, the evidence is moderate for the relationship between exposure and respiratory problems for the occupants. However, the level of evidence for the relationship between ventilation and a reduction in exposure to these contaminants in residential buildings is low, which does not support a recommendation regarding mechanical ventilation. As for determining a minimum ventilation rate, moderate direct and indirect evidence exists to the effect that a rate of 0.5 ACH reduces the frequency of respiratory symptoms, which supports a level B recommendation. However, there are insufficient data for excluding the possible existence of a threshold at a rate below 0.5.

DISCUSSION

Quality of the studies

Several studies were conducted to evaluate, either directly or indirectly, the relationships between the ventilation in residential buildings and the occupants' respiratory health, particularly asthma symptoms in children. For intervention studies, very few randomized studies are available. However, seven

well controlled intervention studies (or 2 direct and 5 indirect) revealed a beneficial effect of ventilation on humidity and mites in the dwelling and the occupants' allergen sensitization and respiratory symptoms. Several cohort and control case studies support this scientific evidence, including the most recent ones. However, some limitations remain, in particular the few studies carried out on non-Scandinavian populations. Although some studies conducted in Great Britain, Australia and North America have shown a reduction in humidity, mites and allergens, extrapolation of the results outside Scandinavia must be carefully done. Also, even if the relationship between exposure to airborne contaminants and a higher frequency of respiratory symptoms in young children is generally recognized, it remains difficult to determine the relationship between this exposure and the development of asthma, considering the uncertainty surrounding the diagnosis of this disease in children. In several studies, in particular the oldest ones, measurement of mould and VOC exposure is based on a questionnaire or on qualitative and not quantitative instruments. Measurement of mite exposure is generally much more objective: mites/g, allergens/g, concentrations of antibodies in the blood, *Prick test*. A common limitation of the different studies on ventilation and health is the non-consideration of the "maintenance" variable for the system, which could mainly have the impact of underestimating the potential beneficial effect of ventilation done under optimum conditions. Some groups of international experts also believe that scientific evidence exists that suggests a link between ventilation and the occupants' respiratory health. Future research in the field of ventilation should address randomized trials as much as possible, even if

such trials are not commonly carried out in the field of environmental health.

↪ Applicability of the results to Québec

We have very few data on the impacts of ventilation in Québec homes. There are probably different ways of evaluating the applicability of the results obtained in the studies carried out globally to the situation prevailing in Québec. However, in the present context, climate seems to play an important role in the efficiency of natural or mechanical ventilation by varying (upwards as well as downwards) the indoor humidity level as well as by indirectly affecting exposure to airborne contaminants. The intervention studies carried out in Denmark, Sweden and Norway revealed that mechanical ventilation had a statistically significant impact on the reduction of humidity, mites, allergens, and even respiratory health problems. Some studies conducted in Great Britain, Australia and New Zealand have also shown a statistically significant reduction in some environmental parameters, including humidity and mites, but without an obvious reduction in respiratory problems. Based on the monthly climatic normals calculated over 30 years by Environment Canada and the World Meteorological Organization, the climates of Québec City and Montréal, for example, are similar to those of the cities located in the centre of Sweden. Winters are particularly cold and dry. Considering this similarity in climatic conditions, it is likely that in Québec, with a comparable ventilation rate, one could expect the same reductions in humidity inside residences as those observed in Scandinavia. This variation in indoor humidity could also be affected by the characteristics of the dwelling and the behaviours of the occupants. However, in general, nothing

indicates that these characteristics could differ markedly from those prevailing in Québec. In this context, in order to verify the similarities in this regard, it seems that these parameters need to be evaluated by appropriate studies in Québec homes.

Minimum ventilation rate

Over the last twenty years, a downward trend in the required minimum ventilation rate has been observed in North America, likely due to concerns about energy conservation. Low ventilation rates are, however, likely to lead to technical feasibility problems, mainly because they make it difficult to balance the system as well as to distribute fresh air and mix it with the ambient air. Furthermore, the results of some epidemiological studies reveal various effects on respiratory health when the ventilation rate is below 0.5 ACH. However, the fact that the researchers examined the possible impacts only in relation to this rate does not exclude the possibility of obtaining a threshold at a different rate. Regardless, several international experts believe that a minimum ventilation rate approaching 0.5 ACH is indicated in countries with cold climates. As we noted, there is a lack of data on the impact of ventilation rates below 0.5 ACH on airborne contaminants and respiratory health. We therefore believe that Québec data on this aspect must be obtained.

Factors likely to affect ventilation efficiency

Considering the random character of natural ventilation, which is difficult to control, available data encourage us to believe that it is preferable, in order to obtain acceptable air flows during all

periods of the year, that mechanical ventilation combined with natural ventilation be considered. In apartment buildings, ventilation facilities similar to those used for individual homes, including individual control of the equipment, should be considered. Like any other type of power-operated installation, a mechanical ventilation system is subject to a certain number of technical constraints that must be considered in order to optimize its efficiency and avoid the occurrence of negative consequences. It is therefore simply not enough to design ventilation systems with a given capacity and make them available, but one needs to ensure that these systems can provide quality air. In addition to the design and selection of the system (including filtration, as needed), one must therefore consider its installation (including the location and balancing of the equipment), preventive maintenance, as well as its use. As suggested by the results of the studies carried out in public buildings and office buildings, each of these aspects, when done in an inappropriate way, can have negative consequences on the expected performance. Even though these results mainly pertain to tight building syndrome, they are an argument for retaining natural ventilation and, in the case where mechanical ventilation is present, for an optimum ventilation rate and for appropriate system maintenance. Therefore, based on our reflection, it appears that the adoption of measures ensuring optimum efficiency could increase the positive impacts observed in the epidemiological studies. This is consistent with making the housing community (builders, contractors, manufacturers, etc.), as well as the public, increasingly aware of the importance of the technical aspects to be considered in obtaining optimal indoor air quality.

CONCLUSION

To provide public health recommendations concerning ventilation in new housing, a systematic review of the literature on ventilation in relation to asthma symptoms was conducted. A comprehensive environmental health framework describing the natural history of allergy and respiratory disease in relation to ventilation was used. We screened studies that provided both direct and indirect evidence related to three indoor contaminants: house dust mites (HDM), molds, and volatile organic compounds (VOCs). Seventy-five (75) studies met our inclusion criteria. The studies were classified according to the level of evidence: randomized controlled trials, non-randomized controlled trials, cohort and case-control studies, descriptive studies, and expert opinions. The relevant preventive measures were categorized according to the appropriate grade of recommendation: good, fair and weak.

Studies in residential buildings directly examining the relationship to mechanical ventilation show a decrease in the frequency of respiratory symptoms and allergy in children. In general, studies on HDM support a link between mechanical ventilation, decreased indoor humidity, HDM and allergen levels, as well as decreased sensitization and decreased respiratory symptoms in sensitized individuals and in children. Most of the indirect studies on ventilation/HDM/asthma are from Scandinavian countries. Some studies done in other countries have shown decreased indoor humidity, HDM and allergen levels, but no decrease in the frequency of respiratory symptoms. Considering the impact of humidity on biological indoor air

contaminants, climate may play a major role. Globally, the literature supports the link between exposure to molds and VOCs and respiratory symptoms in children. However, the impact of ventilation on molds and indoor concentrations of VOCs is not extensively documented. The installation of mechanical ventilation and the provision of adequate ventilation in new residential buildings appear to be fairly well supported preventive measures. Moreover, this review suggests a threshold for health effects between 0.3 – 0.5 air changes per hour. However, important gaps in knowledge remain concerning the impact of ventilation on asthma symptoms in non-Scandinavian countries.

RECOMMENDATIONS

This report was produced with the initial goal of enabling the authorities concerned to make an enlightened choice about the measures to adopt regarding residential ventilation in Québec. It falls within the framework of the mission of the Institut national de santé publique du Québec and the application of section 54 of the *Public Health Act*, which stipulates mainly that the minister of health and social services act as advisor to the government in policies promoting health. The report also falls within one of the objectives of the 2003-2012 *National public health program*, namely that of reducing morbidity due to asthma related to poor indoor air quality in homes and public buildings.

The report has more specifically the purpose of: reviewing the impacts of ventilation on the presence of contaminants potentially found in indoor air as well as on the health of the occupants; identifying the

main technical aspects likely to affect ventilation efficiency; and relating all of the data available in order to determine the most appropriate avenues for the ventilation of Québec residences from a public health standpoint.

Although it answers some questions, we would never claim that this report is an end point in the reflection on ventilation requirements in residential buildings. However, we believe that it identifies a certain number of observations and recommendations, which, we hope, will help in obtaining a better quality indoor environment. These recommendations were formulated from an analysis of the results of epidemiological studies, aspects of a technical nature, as well as the current regulatory context.

Regarding the relevance of mechanical ventilation in Québec residences

Bearing in mind that:

- suitable ventilation of habitable indoor spaces falls within an overall strategy to ensure an acceptable indoor air quality for the occupants;
- residential buildings of today are increasingly airtight and that the natural ventilation obtained previously by infiltration and exfiltration of air as well as by opening doors and windows no longer provides an appropriate and uniform distribution of fresh air in these buildings, particularly during the heating season;
- the available data tend to demonstrate that corridor ventilation facilities for supplying not only outdoor air to corridors but also ventilation air to adjacent dwellings are in reality inefficient

for adequately ventilating each of the dwelling units in apartment buildings;

- the current version the National Building Code contains requirements about the installation of mechanical ventilation;
- direct and indirect scientific evidence reveals that in Nordic countries with climates similar to that of Québec, mechanical ventilation at a sufficient rate can reduce, as opposed to natural ventilation alone, the humidity level, mite proliferation, and occupant exposure to allergens inside the dwellings;
- the scientific evidence also tends to indicate that mechanical ventilation of homes can prevent respiratory and allergic symptoms, in particular asthma-related problems in children and sensitive individuals;
- there is great variability between Québec municipalities in the application of ventilation requirements for residential buildings not subject to the Québec Building Act.

We recommend that:

1. appropriate measures be implemented so that new residential buildings built in Québec, as well as those subject to major renovations leading to increased airtightness of the building envelope, be equipped with a mechanical ventilation system installed according to the best practices, and that is complementary to natural ventilation, and capable of ensuring sufficient ventilation of habitable spaces during all periods of the year;
2. appropriate measures be implemented so that the installation of ventilation in new apartment buildings allow each of the dwelling units to be ventilated at a rate similar to that prescribed for

individual homes, and that necessary measures also be implemented to ensure appropriate maintenance of this installation.

Regarding the required minimum ventilation rate

Bearing in mind that:

- in the absence of sufficient ventilation, there is a higher risk of excessive humidity, poor indoor air quality, and consequently, respiratory health problems;
- too low a ventilation rate leads to certain technical difficulties, mainly in the adequate distribution of fresh air and its mixing with the ambient air, which are likely to compromise ventilation efficiency;
- ASHRAE 62-1999 standard, to which the National Building Code refers, prescribes a minimum rate of air changes per hour of 0.35 for new residences;
- section 9.32 of National Building Code 1995 prescribes an air change rate based on occupancy as a function of the number of rooms in the dwelling unit, which corresponds to approximately 0.3 ACH for an average dwelling unit;
- the results of some studies show a lower frequency of respiratory symptoms at a rate of 0.5 ACH, that groups of international experts recommend a minimum ventilation rate of 0.5 ACH, and that in northern European countries with climates similar to that of Québec, the air change rate prescribed is closer to 0.5 ACH than 0.3 ACH.

We recommend that:

3. the relevance and feasibility of reviewing the current minimum ventilation rate required for residential buildings be evaluated from a public health standpoint. To this end, a consensus conference bringing together experts from research organizations and regulatory agencies could be organized.

Regarding the measures targeting ventilation efficiency

Bearing in mind that:

- the installation of a ventilation system has a decisive impact on the expected performance and on its general efficiency, and as a result, on indoor air quality;
- ventilation, both natural and mechanical, must be considered as complementary measures and part of an overall indoor air purification strategy;
- it is important to avoid the potentially negative impacts of ventilation achieved with an inappropriate method of operation (e.g., a system used sporadically, producing an insufficient air flow, or even a system used continuously at a relatively high rate, leading to excessive drying of the air);
- inadequate maintenance of the ventilation system leads to a risk of reduced efficiency and microbiological contamination of the system's components.

We recommend that:

4. a best practices guide be developed dealing with the technical aspects related to the efficiency of the mechanical ventilation (design, selection, installation, methods of operation, maintenance, etc.);
5. a training program, based on the best practices guide, be offered to specialized ventilation contractors as well as to any other concerned clients from the construction-renovation industry;
6. an awareness and information campaign be conducted with the general public to promote the importance of an integrated air purification strategy (control of contaminant emissions at source, appropriate ventilation of habitable spaces, available resources or programs, appropriate maintenance and use of the ventilation system, etc.) in obtaining good indoor air quality.

✍ Regarding the acquisition of Québec data

Bearing in mind that:

- the results of the studies carried out in the Scandinavian countries that show beneficial effects of ventilation on the indoor environment and respiratory health, as well as the similarities of the Québec climate with that of these countries, where the air change rate required by the standards is closer to 0.5 ACH than 0.3 ACH;
- the lack of Québec data on the real impacts of the different ventilation strategies (natural, mechanical, mixed) as well as the ventilation

rates currently prescribed by the codes on the presence of airborne contaminants and the occupants' respiratory health;

- the lack of data describing the population's perception about the importance of the ventilation of habitable spaces.

We recommend that:

7. a scientific study be carried out on a representative sample of Québec dwellings in order to evaluate the indoor air quality as well as the occupants' respiratory health related to the ventilation of habitable spaces and the parameters that affect efficiency;
8. a two-step experiment be carried out to:
 - i) compare the impacts of different ventilation strategies on the variation in the levels of some air contaminants (humidity, mites, allergens, etc.) and the frequency of the occupants' respiratory symptoms;
 - ii) compare the impacts of different air change rates, in particular those varying particularly between 0.3 and 0.5 ACH, on the variation in the levels of some air contaminants (humidity, mites, allergens, etc.) and the frequency of respiratory symptoms in the occupants.

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IMPACTS ON THE OCCUPANTS' RESPIRATORY
HEALTH – SUMMARY DOCUMENT**

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The summary, as well as the full report, are available in their entirety in electronic format (PDF) on the Institut national de santé publique du Québec web site at: <http://www.inspq.qc.ca>.

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