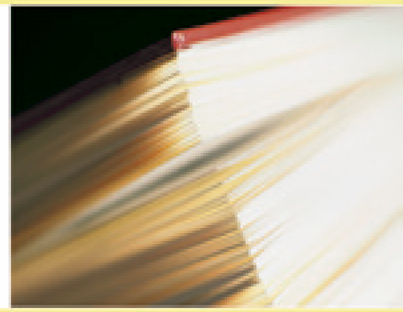
INSTITUT NATIONAL DE SANTÉ PUBLIQUE DU QUÉBEC

Radon in Quebec
Evaluation of the health risk and critical analysis of intervention strategies[*]

SUMMARY DOCUMENT



GENERAL INFORMATION

Radon is a naturally occurring radioactive gas produced from the decay of uranium in the earth's crust. Its presence is ubiquitous at the earth's surface even though its production, and consequently its concentration, are not uniform. Radon can infiltrate into buildings basically through cracks and other routes of entry in the basement. Also, since it is heavier than air, it tends to concentrate in the lowest and least ventilated areas such as basements of homes.

Several different types of equipment are available on the market for measuring residential radon concentrations. Some give instantaneous measurements or over short periods of time, while others provide results over periods of several months. In general, measurement over a long period is considered as giving a precise picture of the real exposure to radon. Since radon's presence is measured using radiometric methods, its concentration is expressed as a function of the radioactive activity attributable to radon in a defined volume of air. It is generally expressed in becquerels per cubic metre of air (Bq/m^3).

Mitigation measures can be implemented to reduce radon infiltration into homes. Some of the most effective methods are those that promote depressurization under the concrete slab. These measures are however not always easy to implement and their effectiveness over the long term has been the subject of very few studies. It is estimated that only a few hundred dollars would be sufficient to implement preventive mitigation measures during the construction of a house. However, the costs associated with the implementation of depressurization measures in existing homes normally

[*] This text is a summary of the scientific report "Le radon au Quebec – Évaluation du risque à la santé et analyse critique des stratégies d'intervention," available in French only on the Institut national de santé publique du Quebec Web site at: http://www.inspq.qc.ca. As a result, any reader interested in obtaining more details about a passage, a particular section, or in knowing the bibliographical references is invited to consult the main document.

vary from $2000 to $5000, but can go as high as $8000 in some cases. Also even if a rather high effectiveness (up to 95%) can be expected, these active measures require the initial expertise of engineering firms that know about this issue and have experience with this type of mitigation adapted to the climatic conditions prevailing in Quebec.

HEALTH EFFECTS

Radon is considered as a human carcinogen. It is classified as a class "A" carcinogen by the United States Environmental Protection Agency (USEPA) and as a group "1" carcinogen by the International Agency for Research on Cancer (IARC). Radon 222 is a chemically inert gas that undergoes spontaneous radioactive decay. Radon progeny are short-lived solid radionuclides, namely polonium 218, lead 214, bismuth 214 and polonium 214. It is these fine solid particles, adsorbed onto aerosols suspended in the air, that are inhaled into the lungs. In decaying, these radionuclides emit *alpha* radiation, which, despite its low penetration, has the capacity to change the cells that line the bronchial walls, producing genotoxic mechanisms susceptible of causing cancer.

Epidemiological studies on workers exposed to high radon concentrations in mines have demonstrated a causal relationship between exposure to radon progeny and lung cancer.

Since the 1980's, several epidemiological studies have attempted to clarify the effects of radon at the doses found in homes. In 1995, the National Institutes of Health (NIH) published a report that presented a meta-analysis consisting of 11 epidemiological studies totaling 68,000 miners and more than 2,700 lung cancer deaths. The authors concluded that there is a linear relationship between cumulative exposure to radon and the risk of lung cancer at the exposure levels documented in mines. The researchers estimated that close to 40% of the lung cancer deaths that have occurred in miners could be attributable to radon and, by extrapolation to the frequency distribution of the radon concentrations in homes in the United States, namely 10% of all the lung cancer deaths that have occurred in the American population. A large source of uncertainty was the extrapolation of the data obtained in highly exposed populations in mines to the generally much less exposed population in homes.

In 1998, the members of the *Biological Effects of Ionizing Radiations VI* (BEIR VI) committee used the epidemiological studies conducted on workers to support risk analysis models applicable to the exposure concentrations found in homes. The BEIR VI committee considered that it did not have at that time sufficient epidemiological studies in homes to evaluate precisely the magnitude of the risk, but endorsed the hypothesis that these studies seemed to support a slight increase in the risk of lung cancer compatible with extrapolations resulting from their models developed from the studies carried out on populations of miners. The authors of the BEIR VI report stated that the slight excess in expected risk was not easily measurable, mainly due to the errors affecting the evaluation of radon exposure. Since 1998, epidemiological studies done in residential settings have reduced the uncertainty associated with the exposure classification bias and tend to rank the risk of pulmonary cancer related to residential radon exposure in the same order of magnitude as that derived from the populations of miners. The studies therefore support the conclusions of BEIR VI that residential radon exposure must be considered, for the general population, as a reducible cause of lung cancer. However, there are still some uncertainties about the magnitude of the relationship to the doses found in homes, mainly in non-smokers, and modification of this relationship by different factors, in particular passive smoking, remains to be determined.

RADON CONCENTRATIONS MEASURED IN QUEBEC

The Ministry of the Environment did the first Quebec radon measurements in the early 1980's. A study to define residential exposure in Quebec was conducted in 1992-93 on approximately 900 homes in the province. Local interventions were then carried out by the Direction de santé publique des Laurentides in the Oka parish sector in 1995 and 1996 and in the Saint-André d'Argenteuil sector in 1998, by the Direction de santé publique de la Montérégie in the Mont Saint-Hilaire sector in 2001, and finally by the Direction de santé publique de la Côte-Nord in the Baie Johan-Beetz sector in 2004.

The Quebec population seems relatively unexposed to residential radon when compared to those in a large number of countries that have been evaluated on this subject. Some sectors, such as those with a geological formation suitable for radon emission, are however likely to have concentrations significantly higher than the Quebec average. Apart from these sectors, the concentrations measured in risk zones remain relatively low and compare to the average values measured in several countries. In fact, based on information available in the Quebec housing inventory in 1991 (namely a total of approximately 1,470,000 homes excluding apartment buildings) and on results of the radon concentrations measured in the Quebec study, the number of houses in the province where radon concentrations greater than 800 Bq/m^3 can be measured on the ground floor can be estimated at approximately 3,231 (IC95%: 147-18,065). Approximately 19,680 houses (IC95%: 3,966-35,249) probably have concentrations above 200 Bq/m^3 on the ground floor, and 35,984 (IC95%: 18,065-63,742) with concentrations above 150 Bq/m^3.

REFERENCE VALUES ADOPTED BY DIFFERENT COUNTRIES

Establishing a reference value is an essential step in any intervention strategy, and most countries have defined one or more reference values for residential radon that serve, so to speak, as guidelines for the interventions. The highest values generally establish the line between an acceptable and an unacceptable risk. When the concentrations exceed this level, it is generally recommended that correction measures be rapidly applied, regardless of the costs associated with the implementation of these measures. The values that can be classified in this category vary between 400 Bq/m^3 (Sweden) and 1500 Bq/m^3 (Czech Republic), but most are between 740 Bq/m^3 (United States) and 1000 Bq/m^3 (Germany, Switzerland, France, Belgium). In all countries except Canada, when a value expressing the concept of unacceptable risk is defined, it is always accompanied by a second value that is not as high. This **low value** often corresponds either to a level below which it is unnecessary to act, or to an objective to be reached. In the majority of cases, the reference concentrations defined for homes do not have force of law. Instead, they correspond to guidelines. For future homes, reference values vary, depending on the country, between 150 Bq/m^3 and 1000 Bq/m^3. If these extreme values are excluded, the reference values fall instead between 200 and

400 Bq/m^3. The legal character that is generally given to them is due to the fact that construction rules, which in theory should allow such levels to be reached, are often included in construction codes.

Close to half of the European countries have defined a reference value for radon in the workplaces and in public buildings. In several countries, the reference values in this type of building have force of law. In the majority of cases, the proposed concentrations are between 400 and 1000 Bq/m^3.

The Canadian reference value defines the limit beyond which the risk is considered as intolerable and where rapid action must be taken. In practice, however, it is often considered as a low value below which it is unnecessary to act. This incorrect interpretation of the Canadian value can have the effect of causing some inertia in the population regarding mitigation when the concentrations are below this value. It seems appropriate to add a second value to the value currently used in Canada that is lower than the first, in order to encourage the implementation of mitigation measures by owners of houses with high radon concentrations. This second value should in theory be as low as possible in order to maximize the impact of this measure.

INTERVENTION STRATEGIES

The development of an effective intervention strategy for radon remains complex. The three main elements of such a strategy are:

- A system of reference values for the intervention levels;
- A process for identifying homes (or sectors) that require an intervention;
- A framework for selecting radon control techniques.

To develop the content of these three components, many difficulties must be overcome. The scientific aspects of each component must be considered. Reference values will therefore be based on an understanding of the dose/effect relationship and knowledge about the population's exposure. The home identification process will be based on knowledge about radon's behavior and on sampling strategies and techniques. Finally, the selection framework for radon control techniques will be based on knowledge about the buildings and on experience with specific control techniques.

Besides the scientific aspects of each of the three components, the direct relationships that exist between them must also be considered. As well, many additional aspects must be developed and specified.

These include:

- The players involved;
- The players' respective roles and responsibilities;
- Backup and support measures;
- The tools and means for disseminating information;
- The legislative and regulatory framework related to the intervention;
- Technical and administrative tools for guiding the intervention;
- Technical and professional training activities.

The resulting program therefore consists of a group of resources, as well as strongly interrelated and consistent scientifically-based and feasible activities, in order to achieve predetermined objectives.

The International Commission on Radiological Protection (ICRP) has described its recommended approach to prolonged (or chronic) exposure to radiation, including radon. The ICRP has developed principles that are the basis of the radiation protection system and recommends the use of generic reference values applicable to all situations. However, use of these values requires great care and must not lead to negative effects. By taking into account these warnings, the ICRP considers that an exposure close to 10 millisieverts (600 Bq/m^3) could be used as a generic reference level below which an intervention is not likely to be justified for some prolonged exposure situations. Situations in which the annual dose approaches 100 millisieverts (exposure to 6000 Bq/m^3, 7000 hours per year) would almost always justify an intervention. These levels could therefore be used as generic reference levels in many situations.

For residential radon exposure, the ICRP considers that it is clear that some corrective measures are almost always justified for continuous annual exposures above 10 millisieverts (600 Bq/m^3) effective dose. For simple actions, a lower action level could be considered, although it is impossible to lower the level below the natural background. The choice of an action level for radon should therefore be within the interval from 3 to 10 millisieverts of annual effective dose. The ICRP recommends that the appropriate authority determine the action level within this interval, which corresponds to a radon concentration between 200 and 600 Bq/m^3, for an annual exposure of 7000 hours and an equilibrium factor of 0.4[1].

The ICRP recommends that an action level be used to initiate intervention and facilitate decision-making. It recognizes that the choice of an action level is complex and depends not only on the exposure level, but also on the level of the actions and their economic impact on the community and the individual. Although the owner/occupant may be the one to make the decision to take action or not, clear action levels may be necessary.

The programs implemented vary somewhat in scope from one country to another, and as can be expected, the magnitude of the problem seems to affect in part the level of the intervention strategy implemented.

Regardless of the scope of the policy implemented, governmental authorities base their intervention related to residential radon risk even more on information and on voluntarism than on regulatory actions. However, they are much more likely to legislate regarding public buildings and new homes. Prevention in the case of new homes is also a central aspect of most of the strategies developed. Several countries have in fact integrated measures for reducing radon exposure in new houses into their building construction codes.

Everywhere, geographical hazard zone identification is an important step in the management programs developed. The existence of easily-implemented

1. The potential *alpha* energy in the air of any mixture of radon progeny with a short half-life is the sum of the potential *alpha* energy of the atoms present per unit air volume; it is expressed in joules per cubic metre (J/m^3). At equilibrium, radon's *alpha* energy corresponds to that of its progeny. In an indoor environment, this equilibrium is never reached due to the ventilation and the deposition and adsorption of progeny. The potential *alpha* energy in the air of any mixture of radon progeny can therefore be expressed in radon equivalents at equilibrium. This is expressed as Bq/m^3. The **equilibrium factor** is defined as the ratio of the equivalent concentration at equilibrium over the concentration of parent nuclide, or radon.

effective and sustainable mitigation techniques is an essential aspect in the development of a radon intervention program. Mitigation methods are generally not imposed on owners. Instead, public authorities provide owners with guides and manuals describing the different techniques as well as their effectiveness and cost. The feasibility of the different mitigation techniques is an important aspect to consider in developing a radon intervention policy.

In the majority of countries, assessment costs and those associated with the implementation of corrective measures are the total responsibility of the house's owner. However, in a few countries, governmental support is available, under certain conditions, for implementing mitigation measures. Informing the public is often considered as an essential step in the implementation of a risk management policy for radon. Data for evaluating the effectiveness of the programs implemented worldwide are practically nonexistent. However, despite the significant efforts deployed in several countries, it is clear that in the great majority of cases, the number of homes in which steps have been taken to reduce radon exposure remains relatively low even after several years (only between 3 and 6% of owners in the United States had measured the radon concentrations in houses in 1992). The reasons given for justifying non-intervention are the high costs of mitigation measures (50% of the respondents), indifference about radon's risk, and the difficulty obtaining appropriate information about the measures to be implemented. The costs associated with corrective action may also have a non-negligible impact on the public's participation rate.

EFFECTIVENESS OF THE DIFFERENT INTERVENTION SCENARIOS IN QUEBEC

The INSPQ working group attempted to evaluate, by means of a risk analysis, the consequences to human health of the presence of radon in households in Quebec and the possible impact of different intervention scenarios on lung cancer mortality. This risk analysis is based on a model developed by the BEIR VI committee, which chose an empirical approach based on the analysis of data of 11 cohorts of miners exposed to radon. The data were analyzed using a "relative risk" model in which exposure to radon has a multiplicative effect on the rates of lung cancer attributable to the background.

The BEIR VI committee assumed that the relationship between the risk of lung cancer as a function of radon exposure should be a linear model and that a safety threshold would be impossible to determine. In other words, all exposures lead to risk. The BEIR VI committee described the effect of the synergy between radon exposure and smoking by using a submultiplicative relationship. The BEIR VI members developed two models, namely the exposure-age-concentration model and the exposure-age-duration model, and have no preference regarding the validity of one model over the other. For purposes of risk analysis for Quebec, the working group chose the most cautious estimates, namely those calculated using the first of these two models. The calculations relating to lung cancer deaths were done for a life span of 80 years. However, for most of the scenarios developed, the results are presented as the number of deaths per year.

Obviously, the development of risk analysis models such as those developed by the BEIR VI committee is an exercise that, despite all the rigor with which it was done, remains subject to much uncertainty (uncertainty about the values derived from data on miners, uncertainty about the use of the model in a residential context, uncertainty about the estimation of the distribution of exposure values in the population, etc.).

According to the evaluation carried out in this study, approximately 10% of the lung cancer deaths (430/4,101) in Quebec would be attributable to residential radon exposure. However, the available information shows that persuading the population to perform screening tests can be a huge challenge, and that even screening showing high concentrations will not necessarily result in the implementation of mitigation measures for these houses, whether the means are cost-free or not. As a result, different scenarios have been developed, based on data collected from the literature regarding the realistic percentages of people carrying out radon screening, and its mitigation, if need be, in the context of prevention programs.

The first scenarios studied for the Quebec population considered the implementation of measures to reduce residential radon concentrations province-wide, while other scenarios instead considered intervention programs, which, as in some countries, would target only those regions considered as at risk or even localities with a high proportion of houses with high radon concentrations. Lastly, a final scenario studies the effects of a program focusing on radon exposure in schools.

The implementation of an intervention program that would target a reduction in residential radon concentrations in the entire housing inventory by using the most effective measures wherever concentrations are above 150 Bq/m^3 with a universal coverage of the population would reduce the number of lung cancer deaths by 71 cases/year, or a total slightly lower than that associated with a 1% reduction in the rate of smoking (78 deaths/year caused by the 10 main pathologies associated with smoking, including 30 lung cancer deaths/year). In the context of a more realistic scenario in which 6% of the population would carry out screening each time they move and where mitigation measures would be implemented in 12 and 32% of homes with respective concentrations between 150 Bq/m^3 and 800 Bq/m^3 and above 800 Bq/m^3, the program would reduce the number of annual lung cancer deaths by an average of 0.8 cases/year.

The expected benefits of a program targeting an administrative region with possibly higher concentrations than most regions in Quebec were evaluated by assuming that the efforts deployed would result in participation rates two times higher (screening in 12% of homes on each move, mitigation work in 24% and 32% of homes respectively with concentrations between 150 Bq/m^3 and 800 Bq/m^3 and above 800 Bq/m^3) than those retained in the provincial scenario. For these purposes, the Gaspe region was chosen. Such an intervention program would reduce the number of annual lung cancer deaths in this region's population by 0.09 cases/year (0.1% of the 88 annual lung cancer deaths).

The Oka parish risk sector was chosen for evaluating the impact of a local program. It contains a geological formation very favorable to the presence of high radon concentrations. The probability of measuring radon was set at 68%, and the probability of providing mitigation measures was 18% and 53% with respective concentrations between 150 Bq/m^3

and 800 Bq/m^3 and above 800 Bq/m^3. Of a total of 0.35 cases/year of lung cancer deaths in the population involved, a program operating according to these parameters could lead to a reduction of 0.05 cases/year (or 14%). Even if the risk levels are high (in the order of 1 chance in 13 of dying of lung cancer due to radon in male smokers to 1 chance in 104 in non-smoking women according to the estimates), the implementation of mitigation measures in this small population would have little impact on the number of lung cancer deaths in Quebec. However, the small impact provincially does not suggest that no steps should be taken to reduce radon exposure in such a sector. The calculated result of an effective intervention program in this community is a 14% annual reduction in lung cancer deaths. Also, exceptionally high measured concentrations may lead to a high individual risk and alone justify the implementation of an intervention plan.

Even though no data currently exist on radon concentrations in Quebec schools, the working group developed a scenario for these institutions by using the distribution of concentrations measured on the ground floor of Quebec homes as an exposure measurement. From the analysis done on exposure in these environments, 188 deaths could be prevented over an 80-year period (or 2.36/year) if the concentrations above 150 Bq/m^3 were reduced using the best technique available, making this scenario a promising one. However, it should be noted that the concentrations in large public buildings are generally lower than those measured in single-family homes. Thus, the risk is probably overestimated, and consequently the number of avoidable deaths following mitigation work, when the concentrations are 150 Bq/m^3 or more.

RISK ANALYSIS AND RISK MANAGEMENT

Effective risk control involves the implementation of a program, which we define as a set of organized, coherent and integrated measures and activities that reduce or prevent exposure to this risk in the target population, by using appropriate resources. Reduction or prevention of this exposure, to the extent possible, should translate into a reduction in the risk and in the incidence of the targeted health problem.

The choice of an effective program must be based on criteria, including the effectiveness of the interventions, but also on economic, legal, and ethical feasibility criteria and others. The risk management process covers all of the following steps:

1. Defining the problem and its context;
2. Evaluating the risks (determining the dose-response curve and estimating the exposure);
3. Identifying and examining the risk management options;
4. Choosing the management strategy;
5. Applying the interventions;
6. Evaluating the process and the interventions.

This report is intended to contribute to the three first steps and to support the decision-maker who will have to choose the management strategy (fourth step). This document's recommendations should identify the programs most likely to have a significant impact on public health.

The perspective chosen for a risk management objective represents the main public health concern related to radon exposure, and therefore involves the population's risk of developing lung cancer. The perspective reflects a populational view of health. Consequently, the objective of risk management is to have a significant impact on the Quebec population's incidence of lung cancer.

From the BEIR VI committee's exposure-age-concentration model and parameters used by the current working group, it is estimated that radon may be associated with approximately 430 of the 4,101 lung cancer deaths observed per year in Quebec. Most of these 430 deaths would occur in low exposure situations, such as those found in the majority of houses. The threshold at which a house is considered as having a high radon concentration therefore has an impact on the number of cancers that will be avoided by an intervention (Table 1).

TABLE 1

Number of lung cancer deaths theoretically avoidable per year in Quebec as a function of the chosen intervention threshold

Intervention threshold (Bq/m^3)	Number of deaths theoretically avoidable	Proportion of the 430 radon-related lung cancer deaths theoretically avoidable (%)	Proportion of the 4,101 lung cancer deaths theoretically avoidable (%)
150	71.0	16.5	1.73
200	36.0	8.4	0.88
400	26.4	6.1	0.64
800	10.8	2.5	0.26

Smokers represent a group particularly at risk of developing radon-related lung cancer. It is estimated in fact that approximately 60% of the radon-related lung cancer deaths will involve smokers, while 30% will involve ex-smokers, and 10%, non-smokers. The interaction between tobacco and radon is more than additive but less than multiplicative. Therefore, total elimination of smoking would avoid approximately 300 of the 430 radon-related lung cancer deaths.

Although intervention (or remediation) is the main means that can be considered for reducing radon's health impact, high exposures can also be prevented by acting on the building during its construction. This approach, although it involves only the population residing in these new buildings, has the benefit of reducing the exposure of this entire population, since it reduces even low levels of radon. Since most radon-related cancers involve individuals with low exposure, a greater impact can thus be achieved than with remediation alone. Therefore, the incidence of radon-related lung cancer could be reduced by half in the population residing in buildings constructed to prevent radon infiltration, if the chosen hypothesis is that these measures reduce radon exposure by half in houses thus constructed.

The method applied here consists first of developing a profile of the main existing intervention options. These options will then be evaluated on the basis of their effectiveness and their feasibility of application.

Effectiveness is defined here as the capacity to have building owners and managers know about this contaminant, to prompt them to take steps, to take action when there is a high result, to offer mitigation measures that are known to be effective in the sustained reduction of contamination levels, and ultimately, to reduce the rates of lung cancer related to residential radon.

An intervention's feasibility is defined as its capacity to be put into practice in its own context, meaning by taking into account aspects that can promote or slow its implementation. These usually correspond to legal, political, economic, organizational, sociocultural and ethical aspects. However, the provincial political dimension will be only briefly discussed here, because it is more the responsibility of the decision-maker than its authors.

The main existing intervention options are the following: the status quo; health education; promotion of screening in risk zones; screening in risk zones with an offer of financial and technical support for mitigation; obligatory and universal residential screening; obligatory screening in public buildings; obligatory screening in risk zones; and finally, the adoption of preventive measures in the Quebec Building Code.

In the case of the status quo, there is nothing that allows a foreseeable reduction in the 430 lung cancer deaths, even if the screening services offered by private firms are increased. In fact, as long as questions remain about the indicators used by these firms to target their territory and about their mitigation expertise, it will continue to be impossible to interpret their activities in terms of impact on the population's health.

An option such as **education** to promote screening, with 0.8 deaths prevented per year in Quebec and a 0.19% reduction in radon-related mortality, could be presented as a cancer prevention program. Remember that this scenario was not carried out from the perspective of considering individual risk.

Effectiveness is not significantly increased by concentrating **communication activities in zones considered as at risk** (reduction in specific mortality of 1%). Instead, **financial and technical support** should be offered so that there can be concrete efforts to reduce exposure. This support could then increase an intervention's effectiveness to 14.3% in reducing the annual mortality attributable to residential radon in the target population. The reduction in mortality estimated here is of the same order of magnitude as that targeted by cancer screening interventions.

Universal coverage, a scenario assuming that radon will be measured in all Quebec houses and that effective and sustainable mitigation measures will be automatically implemented wherever radon concentrations exceed 150 Bq/m^3, could reduce radon-related mortality by 16.5% (or 71/430). However, this ideal scenario reflects a theoretical effectiveness, in contrast to the estimated effectiveness of the other options, which was calculated from realistic scenarios. In this context, it is impossible to evaluate the number of deaths that could actually be prevented using **obligatory and universal screening,** for which the population's compliance is not really known.

Because **obligatory screening in public buildings** involves child-care and school environments, it is also one of the only options (added to the adoption of preventive measures in the Building Code) that ensures early control of exposures. Depending on the scenario chosen, the number of deaths prevented by obligatory screening in schools could be up to three times higher than that offered by promoting screening in all Quebec homes. Also, this does not take into account the impact of screening in day care centres and workplaces. However, this scenario must be carefully interpreted because we do not have objective data on radon concentrations in Quebec public buildings or any reliable portrait of the use of these buildings.

Actions during the construction of a home to reduce radon infiltration (protective membrane, depressurization system under the slab) are the most effective options for reducing mortality from lung cancer attributable to residential radon over the long term. Theoretically, action during construction to reduce radon infiltrations could reduce by approximately 50% the number of deaths from radon-related lung cancer following the complete renewal of the housing inventory. Since this last condition cannot be met, the real effectiveness of this option cannot be evaluated in terms of the number of deaths prevented. It is obvious that this option remains the most effective for reducing residential radon concentrations in a sustainable way.

The results of the evaluation of the effectiveness of the different intervention options to reduce the annual mortality attributable to residential radon are summarized in Table 2. Only options applying to all of Quebec are presented.

TABLE 2

Effectiveness of the different options in reducing the annual mortality attributable to radon at the provincial level

Option	Territory targeted	Number of annual deaths attributable to radon[a]	Number of deaths prevented annually[b,c]	Reduction in specific mortality in the target population[d] (%)
Education of the population	Provincial	430	0.8	0.19
Universal coverage[e]	Provincial	430[f]	71.0	16.5
Obligatory and universal screening	Provincial	430	NE[g]	NE
Preventive measures during home construction	Provincial	430	NE	NE
Obligatory screening in public buildings (school scenario)	Provincial	14	2.3	16.4

[a] According to the risk analysis model (BEIR VI) used by the working group
[b] Number of deaths prevented according to the evaluated scenario
[c] The limits of the scenarios used tend to overestimate this number
[d] Number of deaths prevented annually/number of annual deaths attributable to radon
[e] Assumes that steps will be taken in all houses and that effective and sustainable mitigation measures will automatically be implemented when radon concentrations exceed 150 Bq/m^3.
[f] Of the 430 lung cancer deaths that would be attributed annually to radon in Quebec, 215 would occur following exposure to more than 15 Bq/m^3 and 71 following exposure to more than 150 Bq/m^3.
[g] NE = cannot be evaluated.

Despite the many reservations that could justify the status quo, the international trend is to have a residential radon policy or even somewhat structured risk management programs. Although interventions have been carried out in Quebec in well defined sectors, choosing to intervene home-by-home involves the risk of having to manage crisis situations following problems that would not have been brought to light by public interventions.

The strategy of promoting screening in zones at risk is difficult to contemplate in the absence of a technical and financial assistance program, particularly in Quebec. In fact, people generally expect that a problem designated by the public authorities be accompanied by some form of financial assistance, in contrast to the United States where the population seems to have fewer expectations regarding the government.

The obligation to screen in zones at risk adds serious control and monitoring problems. Also, measures imposed with the implicit obligation of categorizing homes as hazardous or not seems like an arbitrary and discriminatory practice, whether it is limited to a zone at risk or applied universally.

However, the recent provincial campaign to identify schools containing sprayed asbestos shows that a structured program for evaluating and controlling an environmental cancer risk can be applied to public buildings.

Changes to the building code seem to be a viable option, but beforehand, the target territories must be defined, as well as the effectiveness and safety of the measures imposed, and the control and follow-up mechanisms for their application.

Finally, limiting the evaluation of the relevance or feasibility of risk-reduction interventions to an estimate of their impact on a population's health and to their cost clearly does not demonstrate a concern for treating the person as an end it itself. Therefore, considering the personal risks related to high residential radon concentrations, knowledge about radon-related risks should be made more accessible through education and information.

CONCLUSION

The members of the working group arrived at a conclusion, based on available data, on the following aspects:

Exposure levels found in Quebec

Radon exposure in Quebec is generally low, even though high levels are observed; the latter are found in part in zones favorable to high radon levels, which are also called "zones at risk." Some of these zones are well known, but knowledge about the other zones is limited. The contribution of drinking water and construction materials to radon exposure must also be documented.

Dose-response relationship

Despite some uncertainty, all of the knowledge suggests a link between residential radon exposure and lung cancer. The radon working group used the BEIR VI model to estimate the health risks. This model does not propose any threshold below which there is no radon-related risk, and it considers that the effect of a combined exposure of tobacco and radon is greater than the sum of their individual effects.

Estimated impact on health

Radon is probably responsible for approximately 10% of the Quebec lung cancer deaths. This makes it one of the most important environmental risk factors. However, most of the cancers would occur in individuals exposed to low doses of radon and could not be prevented by a program to control high levels. Tobacco's impact on the radon-related risk is such that approximately 60% of the radon-related lung cancer deaths will involve smokers, while 30% will involve ex-smokers, and 10%, non-smokers. Therefore, control of smoking would lead to a greater reduction in the radon-related risk than what can be expected by controlling radon exposure.

Risk management options

There are many options for managing the radon-related risk, and the choice of an option is dictated by many interdependent parameters covering several fields, some of which do not involve health. In the current context, the options that seem the most promising are the adoption of measures in the building code for preventing radon infiltration into new homes, as well as screening for high levels of radon in public places (schools, day care centres, etc.). The effectiveness of a potential program depends on the integration of all of the components and the care given to the development of all of the components.

Reference value system

A reference value must be based on the chosen intervention strategy and must take into account all of the program's components. The values proposed by the national authorities are between 150 and 1000 Bq/m^3, depending on the objectives, but are most often between 200 and 400 Bq/m^3. The current Canadian guideline of 800 Bq/m^3 is generally poorly interpreted and rather unlikely to promote action, even at levels above it. A reference value system must be consistent, clear in its objectives, and avoid any confusion.

Identification process for buildings requiring corrective measures

Research is still needed to clarify the role of methods for identifying radon risk areas within a screening program. Current residential radon screening tests are adequate but rather unavailable in Quebec due to low demand.

Selection of control techniques

Effective methods for controlling high radon levels are available. A competent person must choose the method in order to ensure its effectiveness and safety. However, expertise in this field is rather unavailable in Quebec.

RECOMMENDATIONS

This document should not be thought of as the end point in the process of managing radon-related risks. Instead, it is more a first milestone. We believe that it will allow public authorities to continue this process on more precise foundations. The document presents the state of knowledge and critically reviews the different intervention options. It does not present a detailed program, but instead a process for the gradual implementation of different interventions.

The working group considers that radon-related health risks justify more energetic action and a greater investment of resources than what is currently utilized.

Information and communication activities directed towards the population and the different organizations likely to be associated with the process, as well as the development and production of a guide for managing requests involving specific cases should at least be undertaken.

The working group recommends that the authorities consider the two risk management options that the working group believes are the most promising over the short run in terms of effectiveness and feasibility, namely the adoption of preventive measures in the building code, and radon screening in public places (schools, day care centres, workplaces, etc.).

In the current context, the group is not in a position to recommend the implementation of a program to promote large scale screening in all homes over the short term, due to the uncertainty about this approach and its limited success. It therefore recommends a prudent approach involving the gradual implementation of the conditions necessary for the interventions and proposed programs to be successful. This approach has the advantage of allowing a gradual investment, followed by an evaluation of the possible success of subsequent steps.

The document answers some questions. It also asks a few, which will have to be answered. These will feed reflection. The working group recommends that there now be a public debate fed by other experts and by the public in accordance with the risk management process proposed by the INSPQ while conforming to our democratic institutions.

The working group recommends:

First, that a **follow-up committee** be established under the aegis of the Ministry of Health and Social Services, involving on the one hand, one or more representatives of the public health organizations involved in the radon problem, namely the Institut national de santé publique du Quebec and the public health branches, and on the other hand, the different players essential for implementing the process, such as the Société d'habitation du Quebec, the Régie du bâtiment, and the Ministry of Natural Resources, Wildlife and Parks. The follow-up committee will mainly be responsible for implementing and putting into practice the specific recommendations stated below, and for involving the public in the consultations, when necessary. To meet these objectives, the follow-up committee will establish working groups whose composition will vary with the tasks to be carried out. The radon working group recommends more specifically:

Over the short term

- Developing a communication strategy to inform the population about the health risk associated with residential radon exposure. This strategy could be developed jointly by the health network and the housing community.
- Informing and training different health professionals. The training strategy could be developed by the Institut national de santé publique du Quebec.
- Developing a guide for public health professionals for managing the health aspects of requests involving specific cases of radon exposure of a personal or community nature. Development of the guide could be entrusted to the health network.
- Taking the necessary steps for the adoption of preventive measures in the Quebec Building Code, including at least the measures adopted in the National Building Code.
- Informing and training professionals in the housing and construction-renovation community so that the expertise necessary for implementing corrective measures in homes is reasonably accessible. This information and training work could be carried out under the aegis of the Société d'habitation du Quebec, with the help of the health network, the Régie du bâtiment du Québec and contractors' associations.
- Clarifying the legal aspects pertaining to the radon problem, particularly the obligations related to screening and the disclosure of radon results during a real-estate transaction.
- Integrating procedures against radon overexposure in a synergistic way with continuing efforts in anti-smoking campaigns from a perspective in which this constitutes an important approach to reducing the risk of radon-related lung cancer.

Over the medium term

- The Canadian guideline in its actual formulation uses a value never to be exceeded (ceiling value) and is poorly interpreted and promotes inaction. The working group therefore recommends that management criteria be developed on a populational basis in relation to the strategies used in Quebec and based on an approach involving the establishment of a value (low value), above which action should be taken in accordance with international recommendations, and that representations be made to the federal authorities on this subject (e.g., Radiation Protection Bureau) so that the criteria are harmonized. Authorities in countries with guidelines propose values between 150 and 1000 Bq/m^3, depending on the objectives, but most often between 200 and 400 Bq/m^3. The choice of a strategy that leaves a wide range to government intervention, grants and regulations will lead to the adoption of a higher intervention level than what would have been chosen if the strategy were based on the voluntary and autonomous involvement of owners. The reference value will therefore have to be established in relation to the intervention strategy chosen, and take into account all the components of the program.
- Taking steps with the authorities responsible to adopt a quality assurance program for contractors involved in the corrective measures.
- Taking steps with the authorities responsible to adopt an accreditation system for laboratories performing radon analyses.
- Considering conducting a pilot project to support an action plan targeting interventions (screening, mitigation) in public places (schools, day care centres, workplaces, etc.).
- Taking steps to implement an anonymous provincial registry of radon test results. This registry should be usable on the basis of a sufficiently precise geographical unit to the benefit of the community.
- Soliciting communities involved in research and development, or the university community, in order to:
  - evaluate the relevance and feasibility of identifying high risk zones and screening in these zones. To do this, the aspects necessary for the success of this intervention must be documented beforehand, namely the precision, validity and relevance of the methods (geological, radiometric criteria, etc.) for identifying the risk zones or sectors. The working group would minimally consist of representatives of the Ministry of Natural Resources, Wildlife and Parks, the Geological Survey of Canada, and experts from the university community;
  - document the contribution of drinking water and construction materials to radon exposure in Quebec, from the standpoint where specific interventions could be considered.

Over the long term

- Reevaluating, in light of the eventual addition of new knowledge and/or facilitating factors, the relevance and feasibility of promoting a universal residential screening strategy and of implementing the aspects necessary to carry it out. Among other things, this includes considerations regarding support for the intervention for individuals.

RADON IN QUEBEC
EVALUATION OF THE HEALTH RISK AND CRITICAL ANALYSIS OF INTERVENTION STRATEGIES – SUMMARY DOCUMENT

Under the coordination of:
Jean-Claude Dessau, Medical Advisor
Direction de santé publique des Laurentides and Direction Risques biologiques, environnementaux et occupationnels of the Institut national de santé publique du Québec

The authors and collaborators are mentioned in the full report.

Institut national de santé publique Québec

This summary, the French version, as well as the full report in French only, are available on the INSPQ's Web site: http://www.inspq.qc.ca
Ce document est aussi disponible en français sur le site Web de l'INSPQ au http://www.inspq.qc.ca sous le titre « Le radon au Québec. Évaluation du risque à la santé et analyse critique des stratégies d'intervention ».

Legal deposit – 2nd quarter 2006
Bibliothèque nationale du Quebec
National Library of Canada
ISBN 2-550-46974-7 (printed version) / ISBN 2-550-46975-5 (PDF version)