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Guide for Radon Measurements in Public Buildings

(Workplaces, Schools, Day Cares, Hospitals, Care Facilities, Correctional Centres)

Canada

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(lieux de travail, écoles, garderies, hôpitaux, établissements de soins et centres correctionnels)

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I. Introduction

1.1 Scope and Summary

This document is intended for persons and organizations carrying out radon measurements in buildings that have a high occupancy rate and/or residency period for members of the public and are, therefore, considered "dwellings" for the purposes of radon testing (Government of Canada Radon Guideline, 2007). The types of buildings include, but are not limited to workplaces, schools, day cares, hospitals, care facilities and correctional centres. The purpose of the testing is to evaluate radon levels in order to determine the need for remedial action to protect the occupants.

The scope of this document is limited to guidance regarding types of measurement devices, device placement, measurement duration, and the interpretation of measurements.

Occupational exposure of workers to radon is addressed separately through existing guidelines or regulations such as the *Canada Labour Code* and the *Canadian Guidelines for Management of Naturally Occurring Radioactive Materials* (NORM) (*http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/norm-mrn/index-eng.php*).

1.2 What is Radon?

Radon is a radioactive gas that is formed naturally by the breakdown of uranium in soil, rock and water. It cannot be detected by the senses; i.e., you cannot see it, smell it, or taste it. However, it can be detected easily with radon measurement devices. When radon escapes from the ground to the outdoors, it mixes with fresh air, resulting in concentrations too low to be of concern. When radon enters an enclosed space, such as a building, it can accumulate to high concentrations and become a health concern. Radon can enter a building any place it finds an opening where the building contacts the soil: cracks in foundation walls and in floor slabs, construction joints, gaps around service pipes, support posts, window wells, floor drains, sumps or cavities inside walls. The only known health risk associated with long-term exposure to radon is an increased risk of developing lung cancer. The level of risk depends on the concentration of radon and duration of exposure.

Radon can be found in any building across Canada, but the only way to know how much radon is in a building is to test. The source of most radon in public buildings is the soil on which the building is standing, and for that reason higher indoor radon levels are more likely to exist at the lower levels of the building. In some cases, higher radon concentrations have been found at upper levels, due to radon movement through elevator shafts or other service shafts in buildings, or due to the stack effect. Stack effect refers to the movement of air in and out of a building: warm air rises and exits through the upper parts of a building, drawing new air in through the lower parts of the building. In rare cases, radon may emanate from building materials which could also give rise to high indoor radon levels. To date, the large-scale testing of Federal buildings across Canada has not shown either of these to be significant factors; therefore, current guidance for radon measurement in large buildings is to initially test floors in contact with the ground. Building owners or managers concerned with the potential for radon at upper levels of the building could also test the top floor. If a building is found to have high radon levels when initially tested on lower floors, then upper floors can be tested while the mitigation strategy is being developed to determine if elevated radon levels exist on those upper floors.

1.3 Radon Guideline

Although there is currently no regulation that governs an acceptable level of radon in Canadian homes or public buildings, Health Canada, in partnership with the provinces and territories, has developed a guideline. The current Canadian guideline for radon in indoor air for dwellings is 200 becquerels per cubic metre (200 Bq/m^3). This guideline provides Canadians with guidance on when remedial action should be taken to reduce radon levels.

The following guideline was approved by the Federal Provincial Territorial Radiation Protection Committee in October 2006 and adopted by the Government of Canada on June 9, 2007:

> "Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area.
>
> The higher the radon concentration, the sooner remedial measures should be undertaken. When remedial action is taken, the radon level should be reduced to a value as low as practicable.
>
> The construction of new dwellings should employ techniques that will minimize radon entry and will facilitate post-construction radon removal, should this subsequently prove necessary."

Health Canada recommendations for remedial action:

1. **Remediate within 2 years:** Results between 200 and 600 Bq/m^3, Health Canada recommends taking steps to reduce the radon level within 2 years.
2. **Remediate within 1 year:** Results greater than 600 Bq/m^3, Health Canada recommends taking steps to reduce the level within 1 year.

While the health risk from radon exposure below the Canadian Guideline is small, there is no safe level of radon. It is the choice of each building owner or manager to decide what level of radon exposure they are willing to accept.

2. Radon Measurement Duration

2.1 Long-Term Measurements

Radon levels in a building can vary significantly over time. In fact, it is not uncommon to see radon levels change by a factor of 2 to 3 over a 1-day period and variations from season to season can be even larger. As a result, a long-term measurement period will give a more accurate indication of the annual average radon concentration than measurements of shorter duration. Long-term measurements are 3 to 12 months in duration. Higher radon levels are usually observed during winter months when buildings are sealed up.

During this type of measurement, there are no requirements for the occupants to change their lifestyle once the measurement devices have been put in place. Health Canada recommends that the radon test performed in a home or public building be a long-term measurement, ideally conducted during the heating season. Health Canada does not recommend a test of duration of less than 1 month, and a minimum of 3 months is recommended.

2.2 Short-Term Measurements

Short-term measurements are not acceptable to determine radon concentrations for the purposes of assessing the initial need for remediation action. Since radon concentrations vary over time, it is strongly recommended that the result of any short-term measurement be confirmed with a"follow-up"long-term measurement, at the same location within the building, to inform decisions about mitigation.

In rare cases, a rapid indication of radon concentration may be required; for instance, as a confirmation that an implemented mitigation strategy was successful or for follow-up measurements in school testing (See Section 6). Under such circumstances, a short-term measurement (typically 2 to 7 days) may be appropriate.

3. Radon Measurement Devices

There are several radon measurement devices that may be used to test a home or building for radon. These devices fall into two broad categories: those used for long-term measurements and those designed for short-term measurements. The detection devices listed below are currently recognized by Health Canada as acceptable for use in the measurement strategies described in this document. Health Canada recommends that Canadian National Radon Proficiency Program (C-NRPP)-approved long-term radon measurement devices be used (*http://c-nrpp.ca/*).

3.1 Alpha Track Detector

These detectors use a small piece of special plastic or film inside a container with a small defined opening. Air being tested diffuses (passive detector) or is pumped (active detector) through a filter covering a hole in the container. When alpha particles from radon and its decay products strike the detector, they cause damage tracks; the number of tracks is proportional to the radon concentration. At the end of the test period, the container is sealed and returned to a laboratory for reading. The radon exposure duration of an alpha track detector is usually 1 to 12 months.

Figure 1 – Alpha Track Detector

3.2 Long-Term Electret Ion Chamber

This device consists of a special plastic canister (ion chamber) containing an electrostatically charged disk detector (electret). The detector is exposed during the measurement period, allowing radon to diffuse through a filter-covered opening into the chamber. Ionization resulting from the decay of radon produces a reduction in the charge on the electret. The drop in voltage on the electret is related to the radon concentration. The detectors may be read in the home using a special analysis device to measure the voltage or mailed to a laboratory for analysis. The detectors are sensitive to the prevailing background gamma dose rate and the results need to be corrected for this by making an onsite gamma dose rate measurement. This type of detector may be deployed for 1 to 12 months.

Figure 2 – Long-Term Electret Chamber

3.3 Continuous Radon Monitors (CRMs)

This detection category includes devices that record real-time continuous measurements of radon gas over a series of minutes and report the results, generally in hourly increments. Air is either pumped or diffuses into a counting chamber, typically a scintillation cell, an ionization chamber, or a solid state detector. The result using this type of detector is normally available at the completion of the test in the home or building without additional processing or analysis. These detectors are normally deployed for a minimum of 48 hours and therefore can also provide short-term measurement results. These monitors are often useful for performing diagnostic measurements during mitigation, and for initial verification of the success of a radon mitigation strategy. These devices will have methods for storing, displaying, and retrieving the data logged by the device.

In addition, these devices often measure and track additional environmental parameters above and beyond the radon concentration such as temperature, pressure, and relative humidity, and they often have onboard motion sensors which allow radon professionals to discern if they have been moved or tampered with. Although CRMs can also be used to conduct long-term measurements, their high cost generally precludes their use as a long-term testing device.

4. Units of Radon Measurement

Canada, like most other countries, has adopted the International System of Units (SI Units) and thus the Canadian radon guideline is given in units of becquerels per cubic metre (Bq/m^3). In order to be able to compare a radon test result to the Canadian radon guideline, radon measurement results must be specified in units of Bq/m^3 or the appropriate conversion must be applied. (See table below).

Depending on the measurement device used to complete a test, radon gas measurement results may be in one of two units. Please see the table below for conversion calculations.

Type of Device	Units Used	Conversion
Devices that measure concentrations of radon gas	becquerels per cubic metre (Bq/m^3) (Canada)	1 becquerel is equal to 1 radioactive disintegration per second
	picocuries per litre (pCi/L) (United States)	1 pCi/L is equal to 37 Bq/m^3 200 Bq/m^3 is equal to 5.4 pCi/L

Table 1 – Units of measurement

Note: Radon progeny, which are solid metals produced from the decay of radon gas, are often measured in a unit known as a Working Level. Care must be taken in converting Working Levels to radon gas as the ratio between the units depends on a number of factors.

5. Measurements in Public Buildings

5.1 Measurement Strategy

Measurements in public buildings provide a different set of challenges from homes. Hospitals, long-term care residences and correctional facilities are occupied continuously, and so a long-term 3-month measurement should be conducted to give a good estimate of the radon exposure of the occupants. However, most schools are only occupied during the day, five days a week, for the school year (approximately 10 months), which presents a potentially different exposure situation. To account for this, Health Canada recommends that additional, follow-up measurements be collected and considered in the analysis of schools once the initial long-term 3-month test has been performed (see Sections 6.3 and 6.4).

If large buildings are operated in an energy-saving HVAC mode then one could consider using the same method and formula as for schools, for calculating the long-term average during business hours in an office building. This presumes that core business hours for the building occupants are fairly well defined, and that the schedule for modifying the HVAC energy savings program remains unchanged. If significant changes are made to how the HVAC system is programmed, the radon exposure of building occupants would need to be re-evaluated, since radon levels could be different.

5.2 Measurement Location in Public Buildings

Public buildings differ from houses in that the occupants are not usually directly involved in the measurement process. The choice of the measurement device location is constrained by the need for security so that the devices are not easily disturbed or readily accessible to curious occupants.

As well, public buildings usually contain many rooms. A room is the space enclosed by walls that reach the ceiling. For the purposes of radon testing, a room subdivided by partitions can be treated as one room. To provide a representative radon concentration estimate for the building, measurements should be made in each occupied room in a basement or, if no basement exists, on the ground floor or the lowest floor having occupied rooms within the building. An "occupied room" is one in which an individual spends more than 4 hours per day. Radon measurements in the building should be made at the same time and be made in unoccupied rooms if there are plans for them to be occupied in the near future. For larger rooms, one detector should be placed for every 200 m^2 of floor space.

The measurement location should be selected so that there is a reasonable expectation that the measurement device will not be disturbed during the measurement period.

- The preferred device location is near an interior wall at a height of 0.8 m to 2 m (3 to 6.5 feet) from the floor in the typical breathing zone, at least 50 cm (20 inches) from the ceiling and 20 cm (8 inches) from other objects so as to allow normal airflow around the detector. Depending on the detector used, this may be accomplished by suspending the detector from the ceiling. Detectors should be placed approximately 40 cm (16 inches) from an interior wall or approximately 50 cm (20 inches) from an exterior wall.
- The primary purpose of testing is to assess the level of radon to which occupants are exposed. Therefore, areas should not be chosen to test where occupants do not spend much of their time. Efforts should be concentrated on testing occupied rooms in basements or, if no basement exists, the ground floor or the lowest floor having occupied rooms within the building. Particular attention should be paid to rooms above crawl spaces, over slabs, or built into the side of a hill with walls that may be in contact with earth.
- For a complex of buildings, such as a hospital, each building should be tested separately.
- Building owners concerned with the potential of radon at upper levels should also test the top floor.
- Measurements should not be made in bathrooms because relatively little time is spent in a bathroom.
- Measurements should not be made in closets, cupboards, near sump holes, crawl spaces, or nooks within the foundation. Radon concentrations in these areas are not representative of the concentration in the occupied area of the building.
- The device location should not be in air currents caused by heating, ventilating and air conditioning vents, doors, fans and windows. Locations near heat, such as over radiators, near fireplaces or in direct sunlight, should be avoided as some measurement devices may be affected. Similarly, devices should not be placed on or near electrically powered appliances or equipment such as computers, television sets, stereos or speakers as some measurement devices may be affected.

- Measurements collected in buildings without central air conditioning during periods of warm weather are likely to give misleading results due to the very high likelihood that windows will be open during the measurement period. This problem can be reduced by increasing the duration of the test, and underscores the importance of a long-term radon measurement.

Building owners should always consider re-testing whenever major renovations are performed that might substantially change the ventilation or airflow in the building or the use of the rooms in the lowest-occupied level. If substantial changes are made, a 3-month test should be performed during the first heating season after completion of the renovations.

(Refer to Annex 1 for further testing guidance)

5.3 Quality Control

In cases where more than 10 detectors are deployed in a building, care should be taken to ensure an appropriate number of quality control (QC) measurements are made as well. QC measurements generally include duplicates, blanks, and spikes.

Duplicate measurements allow the user to make an estimate of the relative precision or agreement between two measurements. Duplicate measurements should be made at the rate of 10% of the total number of measurement locations (e.g., if 10 detectors are deployed in a building, one duplicate measurement should also be made; if 20 detectors are deployed, two duplicate measurements should also be made, etc.).

Duplicate measurements are made by placing two detectors side-by-side (< 10 cm apart or 4 inches). The locations selected for duplicate measurements should be distributed systematically throughout the entire population of the sampling. Large precision errors can be caused by detector manufacture, improper data transcription or handling by suppliers, laboratories or persons performing detector placement.

Duplicate measurements should be compared by calculating their relative percent difference (RPD). The RPD can be calculated by using the formula below:

$$RPD = \frac{|[Radon]_{Test\ 1} - [Radon]_{Test\ 2}|}{\left(\frac{[Radon]_{Test\ 1} + [Radon]_{Test\ 2}}{2}\right)} \times 100$$

Where

$[Radon]_{Test\ 1}$ is the radon concentration in Bq/m^3 for one detector, and

$[Radon]_{Test\ 2}$ is the radon concentration in Bq/m^3 for the duplicate detector

The following chart provides guidance on allowable variances in RPD for duplicate tests.

Average Test Measurement	Acceptable RPD	Warning Level	Above Acceptable
<75 Bq/m^3	No limits	No limits	No limits
75–149 Bq/m^3	25%	50%	67%
Over 150 Bq/m^3	14%	28%	36%

Table 2 – Allowable variances in Relative Percent Difference

If duplicate results differ significantly from the table above, the problem should be reported to the supplier of the detector and/or the laboratory making the measurement, and the cause investigated. The measurements for the room or area in question may have to be repeated based on the outcome of the investigation.

As part of quality control, besides deploying duplicate detectors, consideration should also be given to incorporating an appropriate frequency of field blanks (generally 5%). Blanks are unopened detectors used to help evaluate any response from sources other than radon during the intended test period.

In the case of radon analytical laboratories, spikes (generally 3% frequency) should also be considered. Spikes are radon detectors that are sent to a facility equipped with a radon chamber and are exposed to a known radon concentration. They are used as a check of the measurement accuracy of the laboratory.

It is also recommended that appropriate laboratory quality control be conducted by the laboratory furnishing the detectors. Calibration of instruments should be routinely conducted as recommended by the manufacturer and, if applicable, by C-NRPP. Laboratories analyzing for radon may also hold other laboratory accreditations such as ISO 9001 or ISO 17025.

6. Measurements in Schools

6.1 Measurement Strategy

Because children spend considerable time at school, minimizing radon levels in schools can significantly reduce their potential lifetime radon exposure.

Schools represent special cases for radon testing in that they may only be occupied for part of the year (approximately 10 months), and the heating and ventilation systems may operate differently at different times throughout the day and night. All of these conditions can affect radon levels during a measurement period. Therefore, obtaining a representative estimate of student exposure requires measurements to be made only while the school is in session, i.e., on weekdays during the school year (see Sections 6.3. and 6.4).

Health Canada recommends that radon testing in schools begin with a long-term test, as described for other public buildings (Section 5.1), carried out for a minimum of 3 months during the school year. Ideally, this will be done during the heating season. Depending on the results, follow-up testing may be required to support a more precise estimate of actual radon exposure (see Sections 6.3 and 6.4).

This strategy may also be appropriate for other public buildings that are only occupied during business hours, such as some workplaces, depending on occupancy patterns and HVAC operations. More information is provided in Section 5.1.

6.2 Measurement Location in Schools

To provide a representative estimate for the school-time radon levels, measurements should be made in the lowest-level occupied classrooms or offices of the building, preferably all at the same time. A radon measurement should be made in each room occupied in a basement or, if no basement exists, on the ground floor or the lowest-level floor having occupied rooms. A room is the space enclosed by walls that reach the ceiling; a room subdivided by partitions can be treated as one room. An "occupied" room is one in which an individual spends more than 4 hours per day. For larger rooms, one detector should be placed for every 200 m^2 of floor space.

The device location should be selected so that there is a reasonable expectation that it will not be disturbed during the measurement period. See Measurement Locations in Public Buildings (Section 5.2) for more detailed device location guidance.

School boards should always consider re-testing whenever major renovations are performed that might substantially change the ventilation or airflow in the building or the use of the rooms on the lowest-occupied level.

In cases where more than 10 detectors are deployed in a school, care should be taken to ensure an appropriate number of quality control measurements (duplicates and blanks) are made as well, as described in Section 5.3.

(Refer to Annex 1 for further testing guidance)

6.3 Follow-Up Measurements in Schools to Determine the Basis for Mitigation

If the long-term radon test result is above the guideline, you should follow-up with a short-term test (up to 5 days) using a continuous radon monitor to determine the average radon concentration during school hours (for example each day from 8 a.m. to 4 p.m.). Follow-up measurements should be made in the rooms where the highest concentrations are found, especially when the results exceed 200 Bq/m^3. This is done with an active C-NRPP-certified continuous radon monitor (CRM) that has the capability to integrate and record a new result at least hourly. Follow-up measurements using the CRM must be for a minimum of 48 hours, and a 5-day test is preferred. The shorter 48-hour test may give inaccurate radon results due to varying weather conditions; the longer 5-day test duration will average out this potential effect. The purpose of the follow-up measurement is to determine if the daytime radon levels (those when students and staff are in the school) are the same as those from the long-term radon test results. The long-term test results will be indicative of radon levels 24 hours a day. If ventilation systems are shut down when the school is not occupied, this could result in higher radon levels experienced during that time. The CRM allows one to conduct hourly measurements and to determine if radon levels vary, to more accurately estimate the radon exposure for students and staff.

6.4 Calculating Long-Term Measurement Results for Schools

The average radon concentration during school hours can be calculated from the radon data obtained from the long-term measurement and the short-term measurement using the continuous radon monitor (CRM). The data from the CRM will provide information to determine the ratio of the average radon concentration during school hours to the overall average radon concentration obtained over the short-term monitoring period. This gives the factor by which to multiply the long-term average radon concentration measurement result in order to obtain the long-term average radon concentration during schools hours.

$$[RADON]_{LTARCDSH} = [RADON]_{LTARC} \times \frac{[RADON]_{STARCDSH}}{[RADON]_{STARC}}$$

Where:
LTARCDSH = long-term average radon concentration during school hours
LTARC = long-term average radon concentration
STARCDSH = short-term average radon concentration during school hours
STARC = short-term average radon concentration

If the long-term average radon concentration during school hours is above 200 Bq/m^3, remedial action is recommended.

An example illustrating the use of the above formula follows. Assume the original long-term month radon test result for a room in a particular school was 275 Bq/m^3. The room was then tested again using a CRM for a 5-day period. The following information was extracted from the CRM data:

Average [Radon] during the entire 5-day period = 288 Bq/m^3

Average [Radon] during school hours (8 AM to 4 PM) over the 5 day period = 176 Bq/m^3

The result for the long-term average radon concentration during school hours would then be:

$$[RADON]_{LTARCDSH} = 275 \text{ Bq/m}^3 \times (176 \text{ Bq/m}^3 / 288 \text{ Bq/m}^3) = 168 \text{ Bq/m}^3$$

This is the value on which the decision to mitigate should be based. In the above example, the room in question has a long-term radon concentration during school hours of 168 Bq/m^3. Since this value is below the radon guideline value, the room would not need to be mitigated. This example assumes that the ventilation system is operating in the same way during the full year whenever the school is occupied. As is always the case, if there are modifications done to the building, or changes made in how the ventilation system operates, the building should be re-tested. If substantial changes are made, a 3-month test should be performed during the first heating season after completion of the renovations.

7. Interpretation of Results

If the long-term measurement results are below 200 Bq/m^3, further measurements are not necessary. It should be noted that, while the health risk from exposure at levels below the Canadian Guideline is small, it may be possible to reduce it even further through remediation.

If the long-term measurement results are greater than 200 Bq/m^3, then remedial action is recommended within the timeframes identified in Table 3.

Radon Concentration	Recommended Remedial Action Time
Greater than 600 Bq/m^3	In less than 1 year
Between 200 Bq/m^3 and 600 Bq/m^3	In less than 2 years

Table 3 – Timeframes to remediate

The responsibility for remediation, and for its associated costs, rests with the owner of the building. Further information can be found in the document, *RADON: Reduction Guide for Canadians* (*http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_canadians-canadiens/index-eng.php*)

Annex I – Recommended Procedure for Testing Radon in Public Dwellings (Buildings and Schools)

Initial Radon Testing

Where to Test

Since high radon levels in a building will be caused by radon entering the building from areas in contact with the soil, test all rooms with floors or walls that are in direct contact with the ground or a crawl space. If there are no occupied rooms on the level(s) in direct contact with the soil then test all occupied rooms on the first occupied level.

Only rooms that are, or might be, occupied by someone for a period greater than 4 hours a day will be recommended for testing. The radon detectors will be deployed for the recommended 3-month test period.

Rooms to be tested are defined as an area with walls from floor to ceiling (or false ceiling). In the case of multiple cubicles within a room, the individual cubicles will not be treated as separate rooms but rather the whole collection of cubicles will be considered as one room.

The size of the room will determine the number of detectors required (exclusive of any blanks and duplicates required for QC testing):

- Rooms in which the entire area is less than 200 m^2 (2153 ft^2)
  - One detector will be deployed
- Rooms in which the entire area is greater than 200 m^2 (2153 ft^2)
  - One detector will be deployed for every 200 m^2 (2153 ft^2)

Where NOT to Test

Bathrooms, kitchens and closets will not be tested. Storerooms and warehouse space that isn't occupied by someone for a period greater than 4 hours a day will not be tested. Indoor parking level(s) within a building are also not to be tested.

Floors to Test

Floors or walls that are in direct contact with the ground or a crawl space will be tested based on the following frequency criteria

- Test all occupied rooms,
- If none of these floor levels have occupied rooms, test all occupied rooms on the first occupied floor level above.

Building Measurement Locations – Floors to be Tested

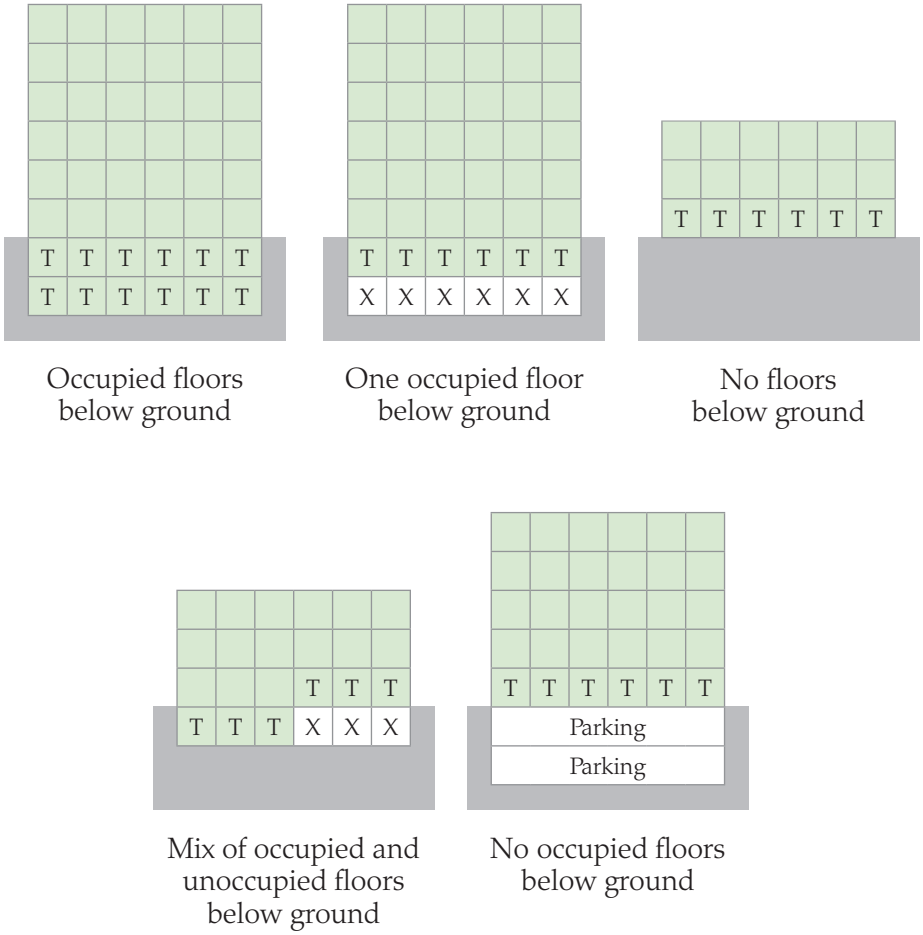


Figure 3 – Recommended radon measurement location in multi-story buildings

Result or Building Average Exceeding Guideline

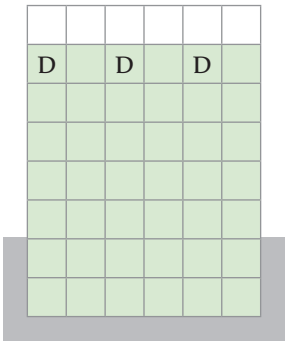
In the event that a result is greater than 200 Bq/m^3 and there is no evidence of tampering during the survey, a re-test is not required except in the case of an anomalous result. If a radon result, floor average, or the building average exceeds the guideline, refer to the Table 3, Timeframes to Remediate, in Section 7.

Optional Diagnostic Testing for Stack Effect or Emanation from Building Materials for Buildings with Radon Concentrations above the Guideline

If, as a result of high initial radon test results, the building owner or occupants are concerned about the potential of high levels on upper floors due to stack effect or radon emanation from building materials then diagnostic testing can be conducted using a continuous radon monitor (CRM).

Where to Test

Occupied rooms on the highest floor to determine radon levels due to a possible stack effect from elevator shafts, other utility shafts, stairwells, or fresh air and heating, ventilation and air conditioning (HVAC) ducts.



Diagnostic testing to determine radon levels due to possible stack effect on the highest occupied floor

Legend:
- Occupied room
- Unoccupied room
- D Occupied room recommended for diagnostic testing

Figure 4 – Radon testing locations in the event of elevated radon results from stack effect or emanation from building materials

Post Mitigation Long-term Testing

Possible Follow-up Testing Situations

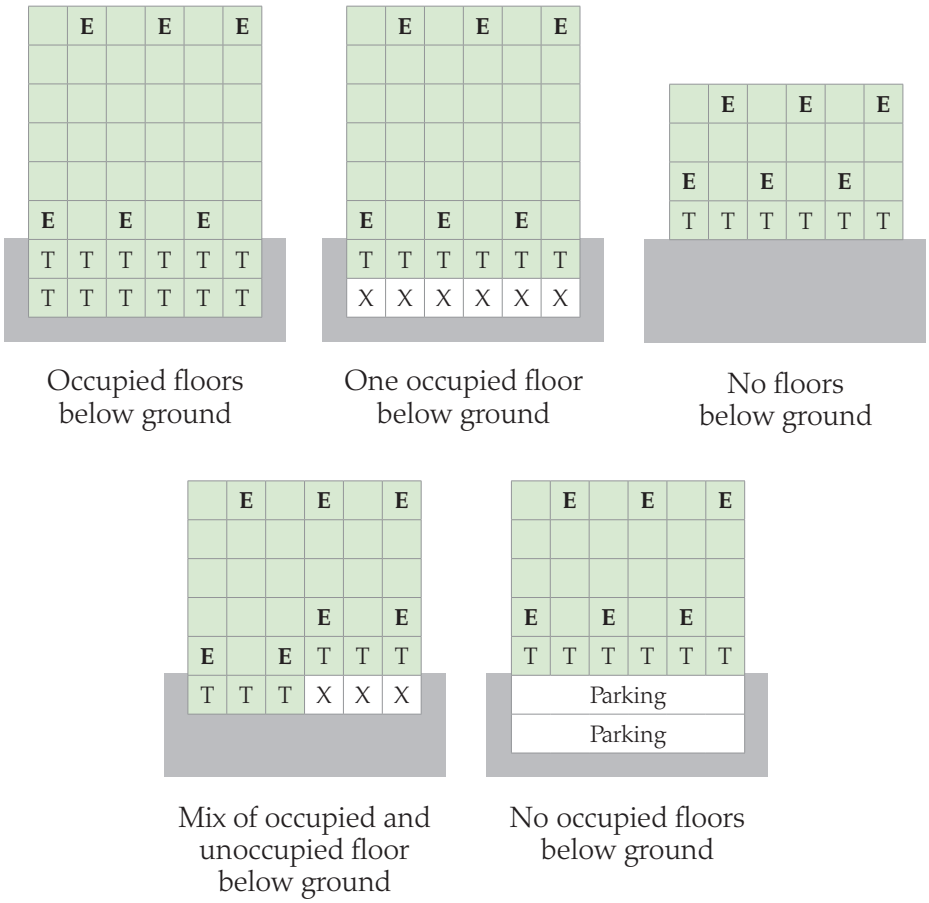
These are two possible situations to look at when developing a radon testing strategy for follow-up testing:

- **Original Location(s)**
  The post mitigation test should be conducted in the same locations that were originally tested, based on the protocol.
- **Extended Testing**
  If the building manager or the Occupational Health and Safety committee requests that other floor levels be tested, then proceed to test the original locations and the locations in the extended plan as noted below.

In the extended plan testing, floors will be tested based on the following protocol:

1. Re-testing the original test locations
2. First floor level that is not in direct contact with the ground or a crawl space:
   a. Test every 3rd occupied room
3. Top occupied floor of the building:
   a. Test every 3rd occupied room
4. Building with five floors or more:
   a. Test every 5th floor (e.g. Floor 5, 10, 15, 20, 25…),
   b. Test every 3rd occupied room on these selected floors

Examples of Floors to be Tested



Legend:
- Occupied room
- T — Represents the first or original round of testing
- X — Unoccupied room, test not required
- E — Post mitigation extended testing
- Parking — Area not occupied, test not required

Figure 5 – Recommended measurement locations for follow-up post-mitigation testing for buildings that have undergone radon mitigation actions

Do ***not*** place the detector in kitchens, laundry rooms, bathrooms, closets, cupboards, sumps, crawl spaces or nooks within the foundation.

Do ***not*** place the detector near heating, ventilating and air conditioning vents, doors, fans, windows, fireplaces, electrically powered equipment, on computers, television sets, stereos or speakers, or in direct sunlight.

Add one duplicate detector for quality control purposes for every 10 detectors deployed for measurements. Place the duplicate detector side-by-side (about 10 cm apart or 4 inches) with the measurement detector.

Annex 2 – Other Measurement Devices

Devices for Short-Term Measurements

Short-term measurements are not acceptable to determine radon concentrations for the purposes of assessing the need for remedial actions.

Activated Charcoal Adsorption

These devices utilize an airtight container filled with activated charcoal and covered with a screen and filter. The detector is opened in the area to be sampled and exposed to the air for a specified period of time. Radon present in the air adsorbs onto the charcoal. At the end of the sampling period, the container is sealed and then sent to a laboratory for analysis using a scintillation detector. Charcoal detectors may be subject to effects from drafts and high humidity. Because the charcoal allows adsorption and desorption of radon to occur, these detectors will give results that are biased towards the end of the testing period if there are large fluctuations of radon levels during the measurement period. In addition, since the lab analysis measures the short-lived decay products, it is important that the kits be mailed back to the lab with the least delay possible to avoid loss of signal. These detectors are normally deployed for measurement periods of 2 to 7 days.

Charcoal Liquid Scintillation

This method is very similar to the activated charcoal detector in that it employs a small vial of activated charcoal for sampling the radon, and hence is subject to the same possible concerns as above. Following exposure, the vial is sealed and returned to a laboratory for analysis by treating the charcoal with a scintillation fluid, then analyzing the fluid using a scintillation counter. These detectors are also normally deployed for periods of 2 to 7 days.

Short-term Electret Ion Chamber

This is the same device described for long-term tests. However, variations in the design of the electret allows for a short-term measurement as well. The short-term electret ion chamber is deployed for 2 to 7 days.

Continuous Radon Monitors

This detection category includes devices that record real-time continuous measurements of radon gas over a series of minutes and report the results in hourly increments. Air is either pumped or diffuses into a counting chamber, typically a scintillation cell or ionization chamber. The result using this type of detector is normally available at the completion of the test in the home or building without additional processing or analysis. These detectors are normally deployed for a minimum of 48 hours.

Digital Detector

This type of detector is not currently recognized by Health Canada as it has not undergone a formal evaluation process with the C-NRPP certification body. Health Canada recommends that only approved long-term testing devices be used for long-term measurements. A digital detector plugs into a standard wall outlet much like a consumer-grade carbon monoxide detector, and continuously monitors for radon. It is a passive device, usually based on an ionization chamber. After being plugged in for an initial period of 48 hours, the device displays the average radon concentration continuously and can be used for short-term or long-term measurements. This type of detector is often used by homeowners that have radon mitigation systems installed in order to continuously monitor radon levels in the home. Unlike the true continuous radon monitors discussed in Section 3.3, these plug-in home-use detectors don't have the ability to download or retrieve the radon measurement data, they do not measure additional environmental parameters beyond the radon concentration, and they may not be as sensitive at measuring hourly radon concentrations as a true CRM.

Continuous Working Level Monitors

These devices record real-time continuous measurement of radioactive decay products produced by radon in the air. Radon decay products are sampled by continuously pumping air through a filter. Alpha particles from the decay of products trapped on the filter are counted to determine the concentration of radon decay products in the air sampled. Continuous working level monitors should be deployed for a minimum of 48 hours.

Specialized Measurement Devices

A number of other specialized measurement methods are also available for radon testing. However, they all require a skilled technician and/or specialized analytical equipment to achieve proper sampling results. These requirements tend to make these measurement methods more expensive than those previously described, and thus they are not commonly used for radon testing in homes or public buildings. Instead, these methods find greater application in research work or to evaluate the success of radon reduction efforts. A list of these methods is provided for information purposes. The methods listed may only be used for short-term measurements.

1. Grab Radon/Activated Charcoal
2. Grab Radon/Pump-Collapsible Bag
3. Grab Radon/Scintillation Cell
4. Three-Day Integrating Evacuated Scintillation Cell
5. Pump-Collapsible Bag (1-day)
6. Grab Working Level
7. Radon Progeny (Decay Product) Integrating Sampling Unit

For additional radon related resources please visit the *Health Canada radon web page* (*http://www.hc-sc.gc.ca/ewh-semt/radiation/radon/resource-ressources-eng.php#a3*).