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Guide for Radon Measurements in Residential Dwellings

(Homes)

Canada

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I. Introduction

1.1 Scope and Summary

This document is intended for persons and organizations carrying out radon testing in residential homes. 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. There is also brief mention of some preventive measures now available for new home construction.

A separate guide is available for assessing radon in public buildings, such as workplaces, schools, day cares, hospitals, care facilities, and correctional centres. (See: *www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_building-edifices/index-eng.php*)

1.2 What is Radon?

Radon is a naturally occurring radioactive gas that is formed 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 home, it can accumulate to high concentrations and become a health concern. Radon can enter a home any place it finds an opening where the house 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. Figure 1 illustrates various radon entry routes. While usually less of a concern, dissolved radon outgassing from water is another potential source of radon in air for homes with groundwater wells (refer to "Annex 4 – Radon from Water and Construction Materials" for more details). 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.

While some amount of radon is expected to be found in any home across Canada, the only way to know how much radon is in a home is to test. The source of most radon in houses is the soil on which the house is standing, and for that reason higher indoor radon levels are more likely to exist in the lower levels of the house.

From 2009 to 2011, Health Canada conducted a cross-Canada residential radon survey in order to characterize the distribution of indoor radon levels in Canada. Long-term (≥3 months) measurements were conducted during the heating season in all geographic areas of Canada. Results indicate that approximately 7% of Canadians are living in homes with radon levels above the current radon guideline of 200 Bq/m^3, and that no areas of Canada are radon free. (See: *www.hc-sc.gc.ca/ewh-semt/radiation/radon/survey-sondage-eng.php*)

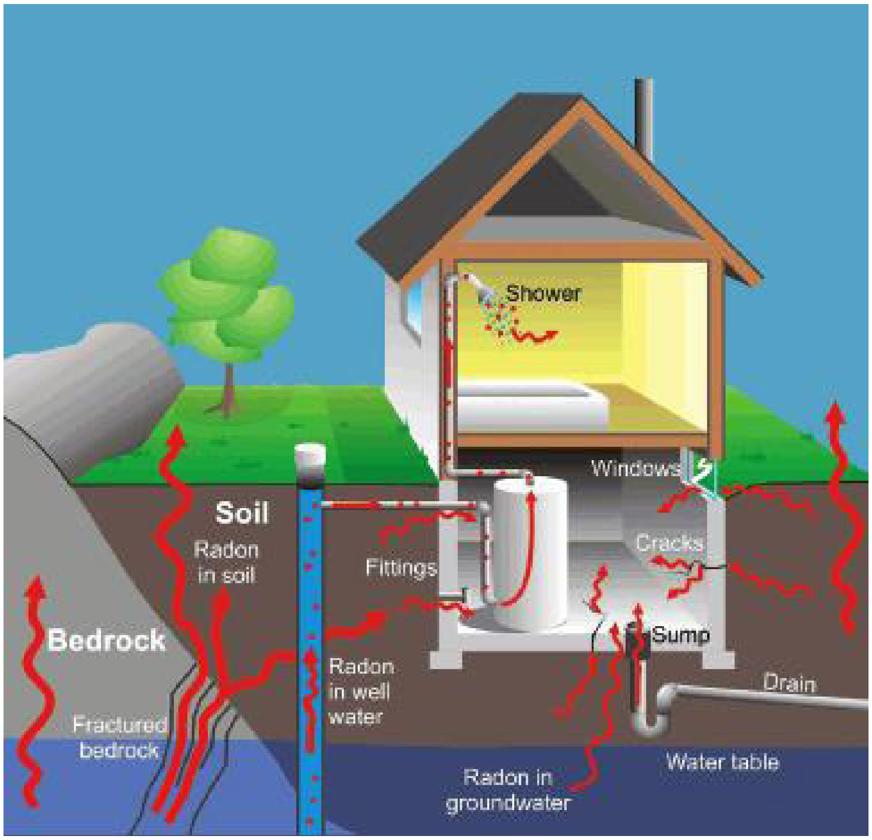

Figure 1 – Radon Entry Routes

Reproduced with the permission of Natural Resources Canada 2008, courtesy of the Geological Survey of Canada

This is a diagram of radon movement indoors as well as outdoors. Because radon is a gas, it can move freely through the soil enabling it to escape to the atmosphere or seep into buildings. When radon escapes from the bedrock into the outdoor air, it is diluted to such low concentrations that it poses a negligible threat to health. However, if a building is built over bedrock or soil that contains uranium, radon gas can be released into the building through cracks in foundation walls and in floor slabs, construction joints, gaps around service pipes and support posts, floor drains and sumps, cavities inside walls, and the water supplies. When radon is confined to enclosed or poorly ventilated spaces, it can accumulate to high levels. Radon levels are generally highest in basements and crawl spaces because these areas are nearest to the source and are usually poorly ventilated.

1.3 Radon Guideline

Although there is currently no regulation that governs an acceptable level of radon in Canadian homes, 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 meter (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 recommendation 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 homeowner[1] to decide what level of radon exposure they are willing to accept.

[1] Homeowner in this guide may mean the proprietor of an individual home, condominium, apartment complex, or multi-unit residential building (MURB).

2. Radon Measurement Duration

2.1 Long-Term Measurements

Radon levels in homes 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 houses 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 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 remedial 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 home, 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. Under such circumstances, an initial short-term measurement (typically 2 to 7 days) may be appropriate. For information on short-term test devices and short-term testing methodology, see Annex 2 and Annex 3 respectively. Any short-term test should be followed up with a long-term measurement.

3. Radon Measurement Devices

There are several radon measurement devices that may be used to test a home 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 with 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 Long-Term 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 2 – Long-Term Alpha Track Detector

The alpha track detector uses a small piece of special plastic enclosed in a container. The detector is exposed to the air in a home for a specified time. When the radon in the air enters the chamber, the alpha particles produced by the decay of radon leave marks on the plastic. At the end of the test the detector is returned to a laboratory for analysis, and the average radon concentration is calculated.

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 3 – Long-Term Electret Ion Chamber

See Section 5 for information regarding detector use, including placement, calibration and quality control.

The Long-Term Electret Ion Chamber is a device that 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.

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 concentration as the ratio between the units depends on a number of factors.

5. Measurements in Homes

5.1 Measurement Strategy

Health Canada recommends that every homeowner test their home for radon through the placement of at least one long-term detector for a minimum of 3 months. Ideally, this testing period should be when indoor radon levels are highest. In Canada, this is typically during the heating season from October to April, when homeowners keep windows closed for extended periods of time, and the thermal stack effect (rising air currents due to buoyancy of air) that tends to draw in more radon gas from the soil is generally strongest.

In homes, radon levels can generally be assessed by measuring in a single location, chosen in accordance with the criteria in Section 5.2.

Radon measurements in newly constructed homes should be conducted during the first heating season after occupancy.

Homeowners should always consider re-testing whenever major renovations are performed that might substantially change the ventilation or airflow in the home 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.

5.2 Measurement Location

To provide a realistic estimate of radon exposure to the occupants, all measurements should be made in the normal occupancy area of the lowest lived-in level of the home. The normal occupancy area is defined as any area occupied by an individual for more than 4 hours per day. Potential measurement locations include family rooms, living rooms, dens, playrooms and bedrooms. Low-level bedrooms (e.g. main floor or basement) should be tested because people generally spend more time in their bedrooms than in any other room in the house. Similarly, if there are children in the home, areas such as basement-level playrooms should be tested. The basement is only considered a potential measurement location if it is occupied for at least 4 hours per day or if there are plans to renovate (add a bedroom or playroom/family room) which will result in occupancy of more than 4 hours per day.

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 rooms in the lowest level of the home where occupants spend at least 4 hours per day.
- 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 home.
- 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.
- Radon measurements conducted in homes 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.

(Refer to "Annex 1 – Recommended Procedure for Testing Radon in Homes" for further testing guidance)

5.3 Quality Control

In the case of large-scale community radon testing of homes, or of multi-unit residential buildings for example, it is important to incorporate additional quality control measurements such as duplicates, blanks, and spikes into a testing program. Duplicate measurements allow the user to make an estimate of the relative precision or agreement between two measurements. 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 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 or 4 inches apart). In the case of multi-unit residential buildings, the locations selected for duplicate measurements should be distributed throughout the entire population of the sampling. Duplicate measurements should be compared by calculating their relative percent difference (RPD). The RPD can be calculated by using the formula below:

Figure 4 – RPD Formula

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

Where

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

$[\text{Radon}]_{\text{Test 2}}$ 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 the precision of the 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 should be investigated. The measurements for the room or area in question may have to be repeated based on the outcome of the investigation.

It is also recommended that the laboratory supplying the detectors have an appropriate quality control and quality assurance program in place. 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.

Homeowners who are interested may wish to perform a duplicate test, whereby two detectors are purchased and placed side-by-side.

6. Interpretation of Measurement Results

If the long-term measurement results are below 200 Bq/m^3, further measurements are not necessary.

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 homeowner to decide what level of radon exposure they are willing to accept. If the decision to mitigate is taken, radon levels should be reduced to a level as low as reasonably achievable (ALARA).

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 house. Further information can be found in the document, RADON: Reduction Guide for Canadians (*www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_canadians-canadiens/index-eng.php*).

7. Radon Preventive Measures in New Homes

Radon levels in a home can vary significantly over time depending upon occupant use patterns and there is currently no way to determine or predict what the radon concentrations within a completed dwelling will be prior to construction. Long-term testing is required after construction and post–occupancy to determine radon concentrations, and mitigation efforts may be required should radon concentrations be found to be above the Canadian guideline of 200 Bq/m^3. Steps can be taken during construction to facilitate the efforts and reduce the cost of mitigation.

There are three main types of radon preventive measures that can be installed in new construction:

Level 1 is a rough-in for a radon mitigation system,

Level 2 is a full passive radon stack,

Level 3 is a full active soil depressurization (ASD) system.

These 3 levels are described in more detail in "Annex 5 – Radon Preventive Measures in New Construction".

It is important for homeowners to realize that the presence of these construction features does not ensure that the radon levels in the home are below the guideline. The only way to know is to conduct a long-term radon measurement and, in some cases, additional mitigation may be required.

Annex I – Recommended Procedure for Testing Radon in Residential Dwellings (Homes)

Where to Test

Place the radon detector in the normal occupancy area of the lowest lived-in level of the home.

IF the basement has finished rooms that are inhabited for four hours a day or more, such as bedrooms, playrooms, family rooms,

Or if the basement will be renovated for purposes where it will be inhabited for four hours a day or more,

THEN test in the basement. Place the device in a basement area that is or will be used for more than 4 hours each day.

IF the basement does not have any areas where people spend more than 4 hours per day (i.e. work, play or sleep),

THEN test on the main level.

In addition, the preferred device location is:

- near an interior wall at a height of 0.8 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.
- approximately 40 cm (16 inches) from an interior wall or approximately 50 cm (20 inches) from an exterior wall.

Where NOT to Test

Bathrooms, kitchens, laundry rooms, closets, cupboards, sumps, crawlspaces or nooks within the foundation should not be tested.

Do not place the detector near heating, ventilating, and air-conditioning vents, doors, fans, windows, fireplaces, electrically powered equipment, television sets, stereos and speakers, or in direct sunlight. For additional guidance, refer to test device deployment instructions.

Acquiring and Interpreting Results

After the monitoring period (Health Canada recommends at least 3 months) is complete, return the detector to the certified radon professional or analytical laboratory for processing and evaluation of radon concentrations. Please refer to Table 3 in Section 6 for recommended remediation timeframes.

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, typically by gamma spectroscopy. 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 lab for analysis by treating the charcoal with a scintillation fluid, then analyzing the fluid using a liquid scintillation counter as opposed to by gamma spectroscopy. These detectors are also normally deployed for measurement 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.

Short-Term Alpha Track Detector

This is the same device described for long-term tests. However, variations in the design of the alpha track detector allow for a shorter measurement period, typically a few days in duration. Refer to test device deployment instructions for additional guidance.

Continuous Radon Monitor

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 (often based on a silicon diode). 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 typically 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 environmental parameters above and beyond the radon concentration such as temperature, barometric 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 (continuous radon monitors) can also be used to conduct long-term measurements, their high cost generally precludes their use as a long-term testing device.

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, often based on an ionization chamber. Some devices require being powered on for a minimum period of time before displaying a concentration. Such devices can be used for short-term or long-term measurements. These types of detectors are 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 (CRMs) discussed above, 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, they may not be regularly calibrated, and they may not be as sensitive at measuring hourly radon concentrations as a true CRM.

For additional radon related resources please visit the Health Canada radon web page:
www.hc-sc.gc.ca/ewh-semt/radiation/radon/index-eng.php

Annex 3 – Conditions for Short-Term Testing

Estimates of radon concentrations obtained through short-term measurements are not acceptable for the purposes of assessing the initial need for remediation.

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 pre-mitigation diagnostic testing. Under such circumstances, a short-term measurement (typically 2 to 7 days) may be appropriate.

Since closed building conditions and a number of other caveats must be followed to conduct a short-term radon measurement, refer to the test device deployment instructions for additional guidance on preparing the house for testing and specific instructions on conducting the short-term test.

Some short-term devices also require the sample to be returned to the analysis laboratory with as little delay as possible due to the short half-life of radon and its decay products. Mailing test kits back to the analysis lab may result in significant delays (e.g. mail delivery times, crossing borders, etc). The longer the delay, the poorer the short-term radon concentration estimate will be (in addition to the uncertainty caused by the short-term variations in indoor radon levels).

Annex 4 – Radon from Water and Construction Materials

Radon in Water

Radon that is dissolved in water can enter homes through the distribution piping. When a faucet is opened, radon dissolved in the water will outgas into the air. This can happen when occupants are showering, washing dishes, or doing laundry, for instance. Outgassing of radon generally only contributes a very small amount to indoor radon levels.

Radon levels in municipally treated water systems are usually extremely low. Radon levels in well water can be significant depending on the source, but very high levels would be required to impact indoor radon levels by an appreciable amount. A general rule of thumb used in the radon profession is that one requires roughly 10,000 times the radon-in-water concentrations per m^3 of water (i.e. 2,000,000 Bq/m^3 radon in water) before radon in water is likely to impact the radon-in-air concentrations significantly. Though such a level is a rare occurrence, it can happen occasionally in private or community wells. If the indoor radon in air concentration in a home tests above the 200 Bq/m^3 guideline, and that home is also supplied with groundwater, testing for radon levels in water should also be considered, particularly if other homes in the community are also known to have high radon in groundwater concentrations. Radon-in-water test kits are commercially available. Depending on the results, it may be necessary to mitigate for radon from the soil, radon from the water, or from both, in order to obtain an acceptable radon in indoor air concentration.

Well water systems with high radon levels can be treated in several ways in order to remove radon from the water before it can outgas into a home. The main techniques used today are aeration (to displace radon), or treatment with activated carbon (to trap radon). Both techniques require consideration of the overall composition of the source water to prevent clogging or fouling of these treatment systems, and the levels of radon in the water. Aeration is the preferred treatment technique for removing high levels of radon from well water.

Radon from Construction Materials

Construction materials such as concrete, drywall, tiles, and granite countertops inside the home, and aggregate materials used under the foundation, may contain low levels of naturally occurring radioactive elements that decay to form radon. This contribution to indoor radon levels is generally very small. For example, Health Canada performed a study of radon emanation from a number of the most popular tiles and granite countertops sold in Canada and found that these added very little radon to levels in homes (see: Radon Exhalation From Building Materials for Decorative Use, Chen, J. et. al., Journal of Environmental Radioactivity, Volume 101, Issue 4, April 2010, pp 317–322). Health Canada has also investigated emanation of radon from aggregate samples from various Canadian sources and, again, found that the samples studied were not significant contributors to indoor radon levels (see: Radon Exhalation From Sub-Slab Aggregate Used in Home Construction in Canada, Bergman, L. *et.al.*, Radiation Protection Dosimetry, Volume 164 (4), June 2015, pp 606-611).

Annex 5 – Radon Preventive Measures in New Construction

A number of measures can be incorporated into new construction of homes to reduce radon ingress and make it easier to mitigate if high radon levels are found from a long-term radon test that is conducted after occupancy. If you are contemplating building a new home, the information provided in this Annex is useful.

A rough-in for an active soil depressurization (ASD) system was included for the first time in the 2010 National Building Code as the minimum preventive measure for radon control in new construction and is to be followed when homes are built in those areas which follow the National Building Code. Specific details of these measures can be found in the current National Building Code manual available from the National Research Council, Canadian Codes Centre (*www.nrc-cnrc.gc.ca/eng/publications/codes_centre/2015_national_building_code.html*).This is referred to in this guide as Level 1. The features of Level 1 are designed to minimize radon ingress and to facilitate mitigation if required after post-occupancy long-term radon testing is performed.

Level 1 – Radon Rough-In

The rough-in consists of a gas permeable layer, a sealed membrane, a sealed sump pit (if the house is so equipped), and a capped rough-in pipe stub. These are described below.

- A gas permeable layer (generally gravel) is intended to allow good airflow under the floor slab (for basements or slab on grade). This is required to make either a passive radon stack (Level 2, below) or an active soil depressurization system (Level 3, below) efficient at drawing radon from beneath the slab. There are requirements for the size of the gravel pieces and the depth of the layer so that the gas permeable layer will be efficient.
- A membrane that is installed underneath the concrete slab but over top of the gas permeable layer acts as an air barrier system to reduce radon entry. This membrane is sealed to the foundation in order to minimize radon entry from the surrounding soil. In addition to sealing the membrane to the foundation before the concrete slab is poured, the expansion or cold joint around the perimeter of the foundation (between the foundation wall and the concrete slab after it has been poured) needs to be sealed as well. All penetrations through the membrane (for plumbing or service pipes etc.) should also be sealed.
- If the home has a sump pit installed, the sump pit lid needs to be sealed to the slab floor and all penetrations through the lid (such as pipes or electrical feedthroughs) must also be sealed. Provision should be made to allow for maintenance of the sump pit area (e.g. maintaining or replacing sump pumps).
- A rough-in pipe stub for a radon reduction system extends down into the gas permeable layer beneath the foundation floor. This pipe is put in place before the concrete slab is poured and where it penetrates the membrane needs to be sealed. The top of the pipe then extends just above the slab/foundation floor. This rough-in pipe stub should be labelled for use as part of a radon reduction system so as not to be confused with plumbing pipes, and the top of the stub needs to be tightly sealed with a glued on cap. This system is only a rough in, and forms the basis for either a Level 2 (passive radon stack) or Level 3 (active fan driven) radon mitigation system.

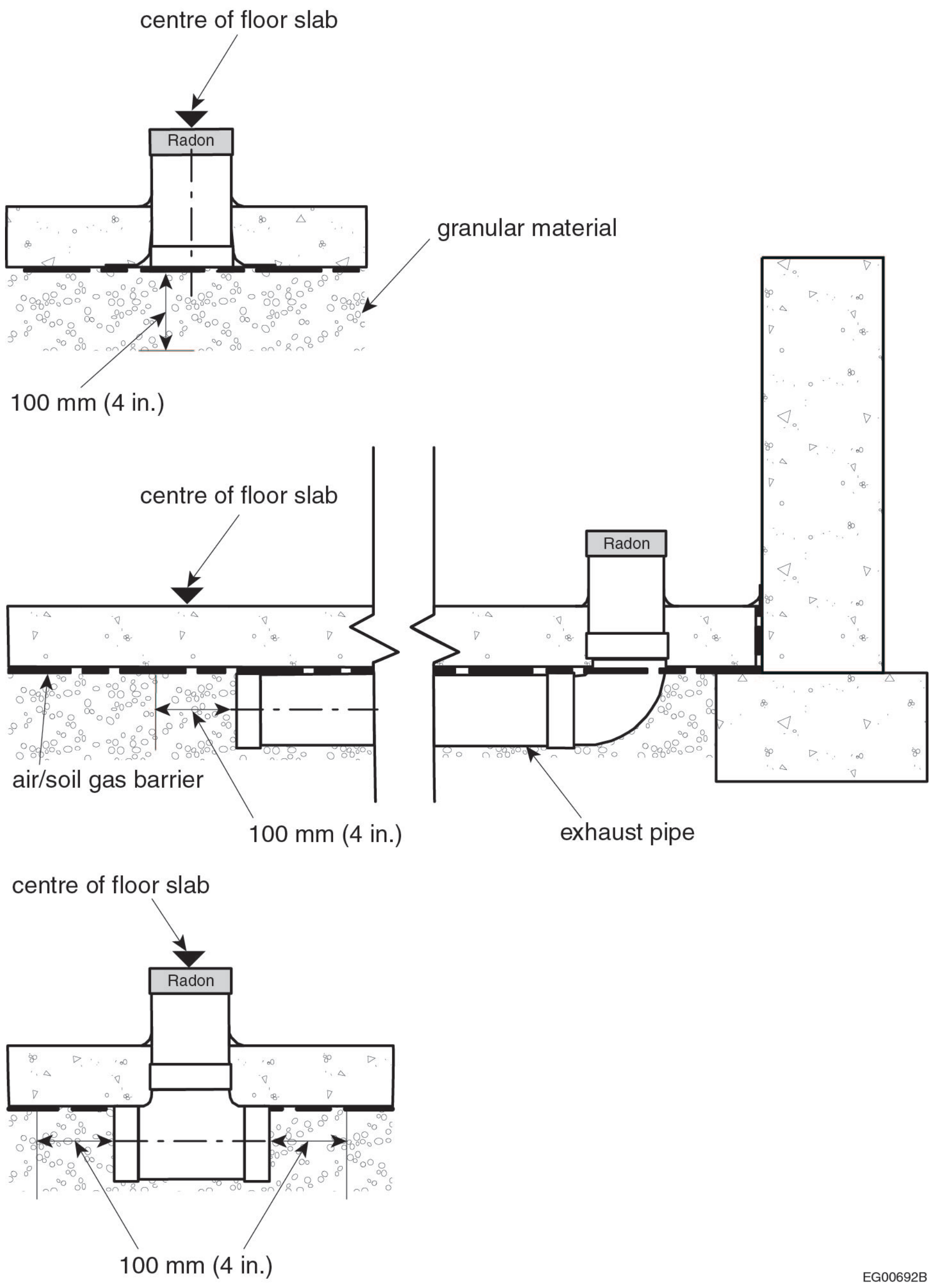

Figure 5 – Level 1 Radon Mitigation Rough-In Installation For Sub–Slab Depressurization System

Figure 5 above is reproduced from the Illustrated Guide to the 2010 National Building Code, copyright holder.

This image demonstrates the basic radon prevention construction measures that can be applied when building a new home. The basic, level 1, application involves the installation of a rough-in stub for a radon reduction system. A piece of pipe is installed through the foundation floor and into a soil gas collector (often gravel), which acts as an entry point for a radon reduction system. The piece of pipe terminates just above the slab and is capped. A membrane is installed underneath the concrete slab which is sealed to the foundation wall in order to minimize radon ingress.

Level 2 – Full Passive Vertical Radon Stack

Level 2 includes the features of Level 1 except that the capped rough-in pipe stub is replaced by a full vertical pipe stack which extends up through the home vertically and discharges above the roofline outdoors. This can be installed in its entirety at construction, or the Level 1 capped pipe stub can have the sealed cap removed and the rest of the vertical stack installed (assuming an appropriate route is available). There are provisions for minimizing pipe bends to maintain the efficiency of the stack and for the outlet of the pipe to ensure re-entrainment of radon does not occur. The system relies on naturally occurring pressure differentials generated by the thermal stack effect (hence the term passive) to draw radon from under the slab and have it traverse upwards inside the pipe stack and exit above the roofline. A properly designed and installed passive system can reduce radon levels by up to 50%. This system is shown in Figure 6 below.

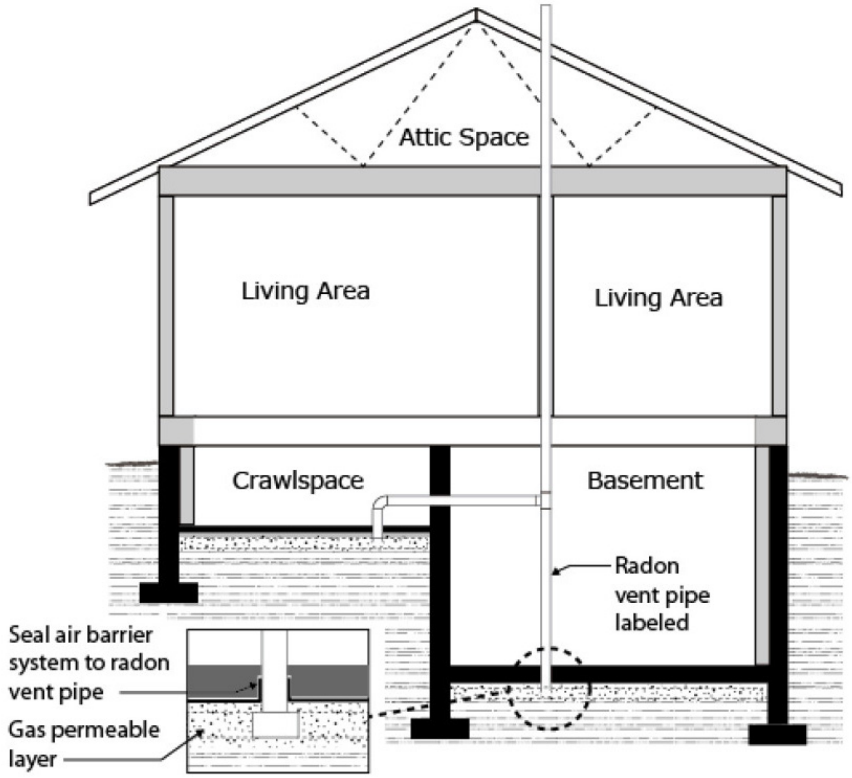

Figure 6 – Level 2 Full Passive Vertical Radon Stack

Figure 6 – Level 2 Passive Vertical Radon Stack (Reproduced with permission from the BC Building and Safety Standards Branch.)

This image demonstrates the installation of a full passive vertical radon stack, a radon prevention new construction measure. A pipe is installed through the foundation floor and into a soil gas collector (often gravel), up through the conditioned space vertically and through the roof to allow for the radon gas to be released outdoors. A membrane is installed underneath the concrete slab which is sealed to the foundation wall in order to minimize radon ingress. This system relies on naturally occurring pressure differentials generated by the stack effect to reduce indoor radon.

Level 3 – Full Active Soil Depressurization (ASD) System

Level 3 augments the Level 2 option of a passive stack by installation of a low wattage fan specifically designed for radon mitigation. The system relies on the radon fan to actively induce a pressure difference to draw radon from under the slab and expel the gas outdoors where it is rapidly diluted. ASD system fans generally run continuously, and a system pressure indicator is installed to allow monitoring of the system.

This method can be installed at the time of construction (e.g. in radon-prone areas), or after a building has been occupied and a long-term radon measurement has been completed to determine if the fan is necessary.

Active soil depressurization systems are the most effective choice for reducing high radon levels in a home, usually to below 100 Bq/m^3. This method should be installed by a qualified professional who is trained in installing preventive measures.

Figure 7 below shows 2 possible examples of a Level 3 full active soil depressurization system. The one on the left discharges perpendicular to the building envelope near ground level with the fan mounted indoors, while the one on the right discharges above the roofline with the fan located typically in the attic. The one on the left is often used if there is only a capped rough-in pipe stub (Level 1) in place. The one on the right is more likely to be used to augment an already existing Level 2 system by mounting the fan in the attic space.

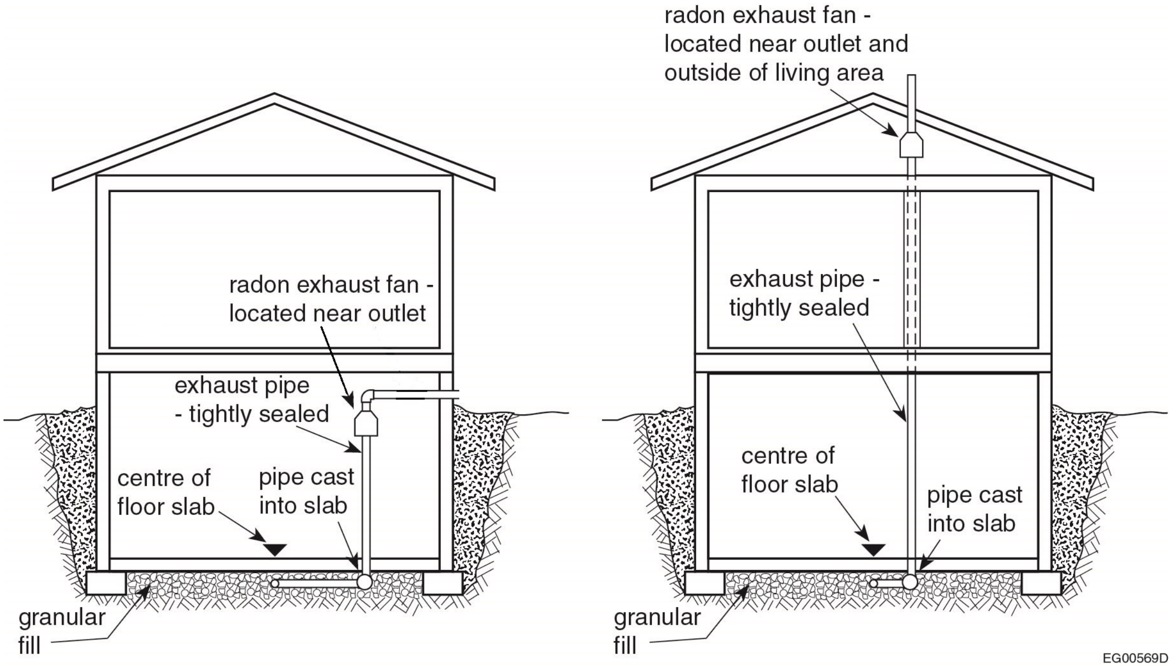

Figure 7 – Level 3 Full Active Soil Depressurization System

Figure 7 – Level 3 Full Active Soil Depressurization System. Adapted with permission from the National Research Council of Canada, copyright holder.

This image demonstrates the components involved in installing an active soil depressurization system. A pipe is installed through the foundation floor and into a soil gas collector (often gravel), up through the conditioned space vertically and through the roof to allow for the radon gas to be released outdoors. A radon fan is attached to the pipe either at the roof level or in the basement. A membrane is installed underneath the concrete slab which is sealed to the foundation wall in order to minimize radon ingress. The radon fan induces a pressure difference to draw soil gases and radon from under the slab and expel it outdoors where it is rapidly diluted.