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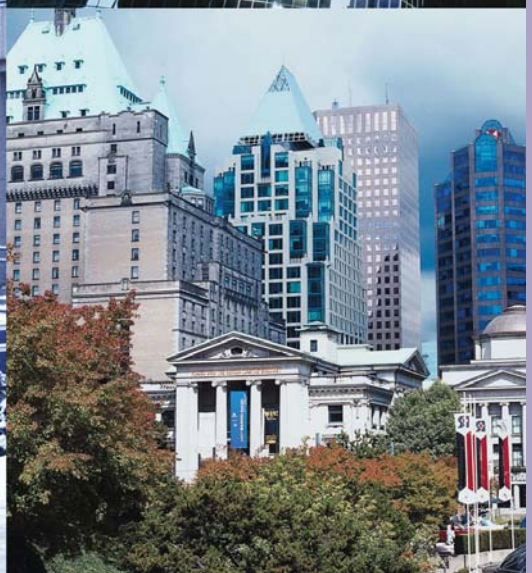
Guide for Radon Measurements in Public Buildings

(Schools, Hospitals, Care Facilities, Detention Centres)



Canada

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1. Introduction

1.1 Scope and Summary

This document is intended for persons and organizations intending to carry out radon measurements in public buildings. These buildings, considered dwellings, have a high occupancy rate and/or residency period for members of the public. The types of buildings include hospitals, schools, long-term care residences and correctional facilities.

The purpose of the testing is to evaluate radon levels in order to determine the need for remedial action to protect the dwelling residents.

Occupational exposure of workers to radon is addressed separately through existing guidelines or regulations such as the Canadian Guidelines for Management of Naturally Occurring Radioactive Materials (NORM) and the *Canada Labour Code*.

The scope of this document is limited to guidance regarding types of measurement devices, device placement, measurement duration, and the interpretation of measurement results regarding corrective action for health protection in public buildings and schools.

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., it is colourless and odourless; however, it can be detected with scientific instruments. Radon usually escapes from the ground into outdoor air where it mixes with fresh air resulting in concentrations too low to be of concern. However, when radon enters an enclosed space, such as a building, it can accumulate to high concentrations. The only known health risk associated with exposure to radon is an increased risk of developing lung cancer. The level of risk depends on the concentration of radon and length of exposure.

Because the source of most radon in public buildings is the soil on which it is standing and radon, which escapes from the soil and infiltrates a building, tends to be heavier than air, 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 elevators or other air shafts in buildings. Health Canada recommends testing every fifth floor in multi-level buildings.

1.3 Radon Guideline

Although there is no regulation that governs an acceptable level of radon in Canadian homes or public buildings (considered as "dwellings"), Health Canada, in partnership with the provinces and territories, has developed a guideline. 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."

(See page 10 on units and page 18 on time frame for remediation.)

2. Radon Measurement Duration

2.1 Long-Term Measurements

Radon levels in a home or other 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. Higher radon levels are usually observed during winter months. As a result, a long-term measurement period will give a much better indication of the annual average radon concentration than measurements of shorter duration. **Long-term measurements are typically 3 to 12 months in duration.** During this type of measurement, there are no requirements for the occupants to change their life-style 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. Health Canada does not recommend a test of duration less than 1 month, a minimum of 3 months is recommended and 12 months is optimum.**

2.2 Short-Term Measurements

In rare cases, a more rapid indication of the radon concentration may be required. Under such circumstances a short-term measurement of duration less than 3 months (more typically 2 to 7 days) can be performed. However, short-term measurements should be used with caution for the reasons cited above. **Testing durations of less than 2 days (48 hours) are never acceptable to determine radon concentrations for purposes of assessing the need for remedial actions.** 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**. The follow-up measurement should be made at the same location as the initial measurement. **A single short-term measurement is not a sufficient basis for a decision to mitigate.** In this case a follow-up measurement is always necessary for mitigation decision-making regardless of the initial measurement result.

2.2.1 Conditions for Short-Term Measurements

Short-term measurements must be made under closed-building conditions to stabilize the radon concentrations and increase the validity of the annual radon concentration estimate. In addition to maintaining closed-building conditions during the measurement, these conditions should be in place for 12 hours prior to the initiation of a measurement lasting less than 4 days, and are recommended prior to measurements lasting up to a week in duration. Closed-building conditions involve ensuring that:

- Windows on all levels and external doors are kept closed for the duration of the test, except during normal entry and exit. Normal entry and exit include a brief opening and closing of a door, but external doors should not be left open for more than a few minutes.
- External-internal air exchange systems such as high-volume, whole-house and window fans are not operated. However, attic fans intended to control attic temperature or humidity may be operated. Combustion or furnace makeup air supplies must not be closed.
- Normal operation of permanently installed energy recovery ventilators (also known as heat recovery ventilators or air-to-air heat exchangers) may continue. In houses where permanent radon mitigation systems have been installed, these systems should be functioning during the measurement period.
- Air conditioning systems that recycle interior air can be operated during the closed-building conditions.

Short-term measurements lasting less than four days should not be conducted during severe storms or periods of unusually high winds. The rapid changes in barometric pressure associated with storms increase the chance of a large difference in the building interior and exterior air pressures, thus changing the rate of radon influx. A high wind increases the variability of radon concentration because of wind-induced differences in air pressure between the building interior and exterior. In either case, the radon concentration during the measurement may not be representative of the average concentration in the building. Weather predictions available on local news stations or weather-reporting Web sites provide sufficient information to determine if these conditions are likely.

Closed-building conditions generally prevail during the cold season from October to April when the average daily temperature is low enough that windows are kept closed. To provide closed-building conditions outside the cold season, the occupants may have to change their life-style for the duration of the measurement.

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 (testing period of 3 to 12 months in duration) or those designed for short-term measurements (testing period of less than 3 months and more typically 2 to 7 days). The detection methods listed below are currently recognized by Health Canada as acceptable for measuring radon in homes and public buildings.

3.1 Devices for Long-Term Measurements

3.1.1 Alpha Track Detector

These detectors use a small piece of special plastic or film inside a container with a filter-covered 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. 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.

3.1.2 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. This type of detector may be deployed for 1 to 12 months.

3.1.3 Digital Detector

This detector plugs into a standard wall outlet much like a consumer carbon monoxide detector, and continuously monitors for radon. It is a passive device based on an ion chamber. It allows one to make radon measurements in different rooms or areas. After being plugged in for an initial period of 48 hours, the device displays the average radon concentration continuously.

3.2 Devices for Short-Term Measurements

3.2.1 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. These detectors are normally deployed for measurement periods of 2 to 7 days.

3.2.2 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. 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 deployed normally for periods of 2 to 7 days.

3.2.3 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.

3.2.4 Continuous Radon Monitoring

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.

3.2.5 Continuous Working Level Monitoring

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.

4. 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

5. Units of Radon Measurement

Canada, like most other countries, has adopted the International System of Units (SI units) and thus the radon guideline is given in units of Becquerels per cubic metre (Bq/m^3). Therefore, in order to be able to compare a radon test result to the 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, the measurement results may be in one of 3 units.

Type of Device	Units Used	Comments
Devices that measure concentrations of radon gas	Becquerels per cubic metre (Bq/m^3) (Canada)	1 Becquerel is equal to 1 disintegration per second
	picoCuries per Litre (pCi/L) (United States)	5.4 pCi/L is equal to 200 Bq/m^3
Devices that measure the radiation emitted from radon progeny	Working Levels (WL) or milliWorking Levels (mWL)	Conversion from WL to Bq/m^3 requires accurate knowledge of contingent factors.

Note: Care must be exercised in converting from units of radon progeny to radon gas as the ratio between the units depends on a number of factors.

6. Measurements in Public Buildings

6.1 Measurement Strategy

Buildings with a high occupancy of long duration by the public, such as hospitals, long-term care residences, correctional facilities, schools and daycare centres are "public buildings" and the Radon Guideline applies.

Buildings where the occupants are employees are "workplaces", and the exposure to radon is governed by different guidelines and regulations, such as the Canadian Guidelines for Management of Naturally Occurring Radioactive Materials (NORM) and the *Canada Labour Code*.

Measurements in public buildings provide a different set of challenges from homes. Hospitals, long-term care residences and correctional facilities are occupied continually, and so a long-term measurement will give a good estimate of the radon exposure of the occupants. As most schools may only be occupied during the day, five days a week, for the school year only (approximately 10 months) a different approach normally is used (see Section 7).

Health Canada recommends the placement of long-term detectors in a public building (hospitals, long-term care facilities, correctional facilities and daycare centres) for a minimum testing period of 3 to12 months (12 months is optimal).

6.2 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 readily accessible by curious occupants. The buildings usually contain many rooms. A room is the space enclosed by walls that reach the ceiling. 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 the lowest-level occupied (occupied by an individual for more than 4 hours per day) rooms of the building, preferably 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 floor with the lowest-level occupied rooms. 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 by 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, however, at least 50 cm (20 inches) from the ceiling and 20 centimetres (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. Detector 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 floor with the lowest-level occupied rooms of 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.
- Measurements should not be made in bathrooms because relatively little time is spent in a bathroom.
- Measurements should not be made in closets, cupboards, sumps, 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 equipment or appliances such as the tops of computers, television sets, stereos or speakers.
- Measurements during the warm weather in buildings without central air conditioning 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.

In cases where more than 10 detectors are deployed in a building, care should be taken to ensure an appropriate number of quality control measurements (duplicates) are made as well. 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 duplication should be distributed systematically throughout the entire population of the sampling. Such duplicate measurements provide a check on the quality of the measurement results and allow the user to make an estimate of the relative precision of the measurements. Large precision errors may be caused by detector manufacture and/or improper data transcription or handling by suppliers, laboratories or persons performing detector placement. If duplicate results differ significantly (results of the two measurements are different by a factor of 2), 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.

Consideration should also be given to incorporating an appropriate frequency of blanks and spikes into any quality assurance plan associated with radon measurement strategies in schools and public buildings.

7. Measurements in Schools

7.1 Measurement Strategy

Schools represent special cases in that they may only be occupied for the school year (approximately 10 months), and the heating and ventilation systems may operate differently at different times throughout the day and night and repair or service work may be in progress when the school is not occupied. All these conditions can affect radon levels during a measurement period. To obtain a representative estimate of student exposure may require measurements to be made only while the school is in session. In addition, an adjustment to correct for day-time exposure (school hours only) may be required for follow-up (see 7.3 for details). Minimizing radon exposure to children at school (since they will spend much time there during their formative years), could serve to reduce their potential overall lifetime exposure.

Health Canada recommends the placement of long-term detectors in schools, where possible, for a minimum testing period of 3 to 10 months (10 months is optimal) during the school year.

7.2 Measurement Location in Schools

To provide a representative estimate for the school-time radon levels, measurements should be made in the lowest-level occupied (occupied by an individual for more than 4 hours per day) classrooms or offices of the building, preferably 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 floor with the lowest-level 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. 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.

- The preferred device location is by an interior wall at a height above the reach of most pupils: 2.5 to 3 m (8 to 10 feet) from the floor, however, at least 50 cm (20 inches) from the ceiling and more than 20 centimetres (8 inches) from other objects. Depending on the detector used, this may be accomplished by suspending the detector from the ceiling.

- The primary purpose of testing is to assess the level of radon to which the 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 floor with the lowest-level occupied rooms of the school. Particular attention should be paid to rooms above crawl spaces, over slabs or built into the side of a hill with wall that may be in contact with earth.
- For a complex of buildings comprising a school, each building should be tested separately.
- Measurements should not be made in bathrooms, closets, cupboards, sumps, 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 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 equipment or appliances such as the tops of computers, television sets, stereos or speakers.

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 in 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) are made as well, as described in section 6.2.

7.3 Follow-Up Measurements in Schools

It is expected that follow-up measurements will 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 continuous radon monitor that has the capability to integrate and record a new result at least hourly. Follow-up measurements using the monitor must be for a minimum of 48 hours and a 7-day test is preferred. The shorter 48-hour test may give unstable radon results from varying weather conditions. The longer follow-up test (7 days) is more likely to average out this effect. The purpose of the follow-up measurement is to indicate if the long-term measured radon concentration is a realistic estimate of the concentration while the pupils are present.

8. Interpretation of Measurement Results

8.1 Long-Term Measurements in Public Buildings

If the long-term measurement results are below 200 Bq/m^3, the average annual concentration in the home or building is probably below 200 Bq/m^3 and further measurements are not necessary and remedial action is not recommended.

If the long-term measurement results are greater than 200 Bq/m^3, then the average annual concentration in the home or building is probably above 200 Bq/m^3 and remedial action is recommended.

8.2 Long-Term Measurements in 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. An average radon concentration during school hours (for example each day from 8 a.m. to 3 p.m.) during the overall short-term (48-hour or 7-day) test period can be obtained from the data collected by the continuous radon monitoring instrument. A ratio of this average radon concentration during school hours to the average radon concentration obtained over the full 48-hour or 7-day (whichever is applicable) short-term test period, gives the factor by which to multiply the long-term measurement result in order to obtain the **long term average radon concentration during schools hours**.

$$[Radon]_{longtermaverageduringschoolhours} = [Radon]_{longtermaverage} \times \frac{[Radon]_{shorttermaverageduringschoolhours}}{[Radon]_{shorttermaverage}}$$

If the long term average radon concentration during school hours is below 200 Bq/m^3, remedial action is not recommended.

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

8.3 Short-Term Measurements

The result of any initial short-term measurement (regardless of the result) should be confirmed with a "follow-up" long-term measurement. The follow-up measurement should be made at the same location as the initial measurement.

If the result of the long-term follow-up measurement is greater than 200 Bq/m^3, then remedial action is recommended.

If the result of the long-term follow-up measurement is less than 200 Bq/m^3, then remedial action is not recommended.

9. Time Frame To Remediate

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
Less than 200 Bq/m^3	No action required

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: A Guide for Canadian Homeowners* (ISBN 0-662-25909-2).

Annex

Government of Canada Radon Procedure for Public Dwellings (Buildings and Schools)

Where to Test

1. Test all rooms with floors or walls that are in direct contact with the ground or a crawl space. If none of these levels have occupied rooms, test all occupied rooms on the first occupied level.
2. Test every 3rd room on the floor level above the floor meeting criterion #1.
3. Test every 3rd room on the top floor of the building.
4. Test every 3rd room of every 5th floor (e.g. Floor 5, 10, 15, 20, 25,…).

One detector is required for rooms of area less than 200 m^2. Larger rooms will require detectors for every 200 m^2. Rooms are defined at an area with walls from floor to ceiling (or false ceiling). Thus cubicles would not be treated as individual rooms. The entire square footage occupied by cubicles would be needed and the area (200 m^2) would be treated as one room.

- Only rooms that are, or might be, occupied by someone for more than 4 hours a day will be tested.
- Bathrooms, kitchens, closets, storerooms and warehouse space will not be tested.
- A 3-month test will be done.

Where to Locate the Detector

The preferred device location is by 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, however, at least 50 cm (20 inches) from the ceiling and 20 centimetres (8 inches) from other objects so as to allow normal airflow around the detector. Detector should be placed approximately 40 cm (16 inches) from an interior wall or approximately 50 cm (20 inches) from an exterior wall. In some schools for instance, to avoid tampering by taller students, the detector may have to be placed at a greater height as described earlier. Similarly, a greater deployment height may also be required in high traffic areas of public buildings. In these cases, depending on the detector used, this may be accomplished by suspending the detector from the ceiling.

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 by 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. If the results of the two measurements (measurement detector and its duplicate) are different by a factor of 2, investigate the problem with the device supplier, analytical laboratory or the person who made the original device placements to correct the problem. Measurements for the room or area in question should be repeated.

Reading the detector

After the monitoring period of 3 to 12 months the detector is returned to the supplier for processing and evaluation of radon concentrations.

IF the long-term measurement results are **less than 200 Bq/m^3**,

THEN remedial action to lower radon concentrations **is not recommended**.

IF the long-term measurement results are **greater than 200 Bq/m^3**,

THEN remedial action to lower radon levels **is recommended**.