Statens strålevern
Norwegian Radiation Protection Authority

2015

PROTOCOL
FOR RADON MEASUREMENTS IN SCHOOLS AND KINDERGARTENS

Regulations on Radiation Protection and Use of Radiation § 4 letter r

Protocol for radon measurements in schools and kindergartens

2015

Established by The Norwegian Radiation Protection Authority (NRPA) 1.7.2015

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1. INTRODUCTION

Indoor radon increases the risk of lung cancer and after active smoking poses the highest risk of developing lung cancer [1]. This risk augments with increased exposure to radon and is proportional to both indoor radon concentration and exposure time. It is the total exposure to radon in the home, at school, at work and during leisure time which is crucial.

Radon is a radioactive gas, which is continually produced from the element uranium which is present in the bedrock. Radon can enter buildings from the soil. The ground is the greatest source of elevated indoor radon concentrations.

The protocol consists of a main section and an appendix. The appendix gives a detailed justification of the points in the main section. Both those responsible for running schools and kindergartens as well as suppliers of radon measurement services are the protocol's primary target audience.

2. AIM

Regulations on Radiation Protection and Use of Radiation (section 6 paragraph 6) set certain requirements to radon levels in kindergartens, primary and secondary schools. This includes both public and private kindergartens and schools. According to The Regulations on Radiation Protection and Use of Radiation (section 4 letter r) radon levels are defined as "the concentration of radon in the air determined according to the measurement protocol in effect at any time as prescribed by the Norwegian Radiation Protection Authority (NRPA)" [2]. Measurements, carried out according to this protocol, will qualify as a documentation of radon levels present in kindergartens and schools.

This protocol can also act as a guide for other large buildings. NRPAs' recommended limits for indoor radon (http://www.nrpa.no/en/topic-articles/91971/recommendations-for-radon-in-dwellings-in-the-nordic-countries) can be employed to evaluate the results from measurements carried out according to this protocol.

3. RADON MEASUREMENTS IN SCHOOLS & KINDERGARTENS

Ventilation is a particularly crucial factor with respect to variation in radon concentration. Balanced mechanical ventilation is the most common type of ventilation in most schools and kindergartens [3 and 4]. This type of ventilation usually results in little seasonal variation in radon concentration [5]. In most incidences, the ventilation systems are regulated by a timer. This means that the ventilation system usually operates at full capacity during the day and at reduced capacity during the night, at weekends and during the holidays. A ventilation system regulated by a timer affects radon concentration resulting in a lower concentration during the day and a higher concentration during the night and at the weekends (see example 3). Radon measurements may therefore have to be performed in up to two individual steps (see chapters 5 and 6 and the flow chart in figure 1). The purpose of step 1 measurements is to determine the possible presence of high radon levels, while step 2 measurements are used to determine radon levels during actual kindergarten/school hours.

Weather conditions as well as heating and airing habits will affect radon levels, in schools and kindergartens with natural ventilation or mechanical extractor fans, to a greater extent than in those with balanced mechanical ventilation. In these types of buildings, the larger differences between the inside and outside winter temperatures will result in a lower air pressure inside the building and a higher inflow of radon from the building ground.

Radon levels, in schools and kindergartens where the ventilation operates at the same level twenty four hours a day, will often be determined using step-1 measurements. If however the ventilation is controlled by a timer for example – radon levels will vary greatly in the course of a twenty four hour period. It may therefore be necessary to carry out step 2 measurements in order to determine the actual level of radon during kindergarten/school hours.

Radon measurement devices, which can measure radon concentration directly during kindergarten/school hours, are also available. By following the stipulations outlined in this protocol for step 1 measurements, radon levels during kindergarten/school hours can be determined using these devices.

The people who frequent the building, such as employees, pupils and cleaning staff, should always be informed that radon measurements are taking place. Information is particularly important in order to avoid the disturbance of measurement devices during the measurement period.

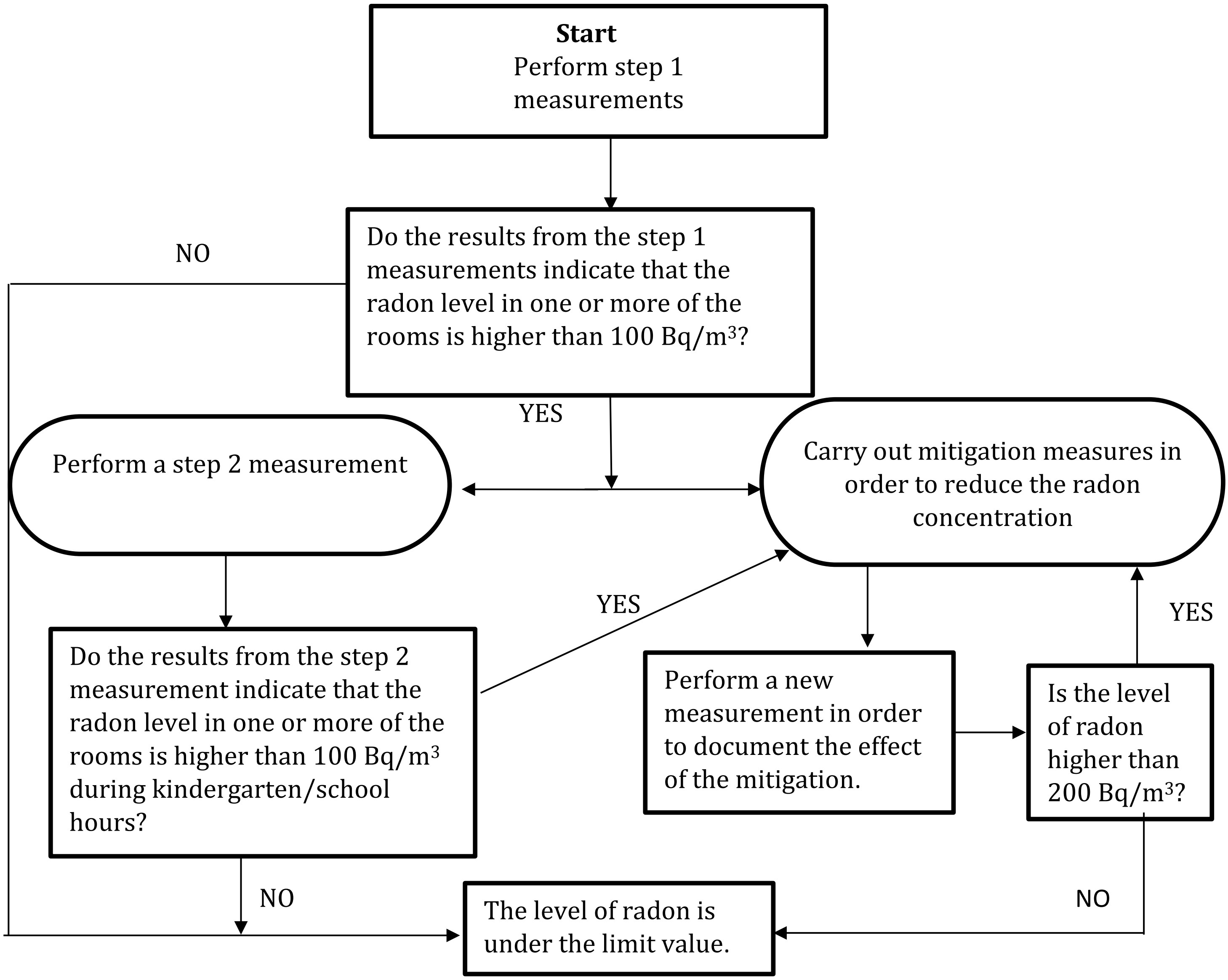


Figure 1: Flow chart illustrating the principals for measuring radon in schools and kindergartens

4. GLOSSARY

Word/Expression	**Definition**
Action level	The action level is the highest annual average radon level which may be accepted before radon mitigation or subsequent radon measurements must be carried out. In the case of schools and kindergartens the statutory action level set by the Radiation Protection Regulation is 100 Bq/m^3 (section 6 paragraph 6).
Annual average radon level	The average radon concentration in the course of a one year period is called the annual average radon level. The annual average radon level may be estimated using the result from a radon measurement carried out during two months (at least) of the 6-month winter period. Seasonal variations are accounted for by multiplying the result with a specific factor (see point 5.6).
Balanced mechanical ventilation	Consists of an aggregate where a time-controlled fan pipes fresh air into the building. This fresh air is subsequently distributed in the building through various channels. Stale air is exhausted from the building in a controlled manner.
Bq/m^3	The measurement unit for the concentration of radon in the air is Becquerel (Bq) per cubic meter (m^3) air.
Controlled ventilation system	A ventilation system which is programmed to function while there are people present in the building. When the building is empty, the ventilation system works at a reduced capacity.

Coverage factor (k)	Factor which is used to calculate measurement uncertainty. If measurement uncertainty has normal distribution and coverage factor k=1 is used (standard uncertainty), then there is an approximately 68% probability that the correct value is within the range of the measurement result ± uncertainty. Using a coverage factor of k=2, this probability is increased to approximately 95%
Etched track dectectors	Detectors which measure the level of indoor radon concentration.
Frequently occupied room	A frequently occupied room is a room, which is frequently used. A class room, a play room, offices, a canteen/dining room, a music room, a wood work room or a gym hall are all examples of frequently occupied rooms. Toilets, technical rooms and storerooms are all examples of rooms, which are not frequently occupied.
In contact with the ground	Rooms where the floor and/or one or more of the walls is in contact with the ground. If a building is built on a slope for example, then several of the floors in the building can be in contact with the ground. A typical ground floor will always be in contact with the ground even if there is a basement/crawl space underneath the building.
Kindergarten/school hours	Kindergarten/ school hours refer to the time of the day when the building is in use. In other words the time of the day when the building is occupied.

Limit value	Limit value refers to the highest annual average radon level which may be accepted in a frequently occupied room. With respect to schools and kindergartens, the statutory limit value set by the Radiation Protection Regulations (section 6 paragraph 6) is 200 Bq/m^3.
Measurement uncertainty	A size connected to the result of a measurement and which describes the range of values in which it is reasonable to expect that the real value lies.
Radon level	The concentration of radon in the air determined according to the measurement procedure in effect at any time as prescribed by the Norwegian Radiation Protection Authority
Six-month winter period	From the middle of October to the middle of April.

5. STEP 1: INVESTIGATIVE MEASUREMENTS

REQUIREMENTS FOR STEP 1 MASUREMENTS

5.1 Investigative radon measurements must be carried out using a method which gives an average radon concentration in the measurement period in accordance with the standards ISO 11665-1 [6] and ISO-11665-4 [7]. Both open and closed etched track detectors as well as electronic measurement devices can be used.

5.2 All types of measurement equipment must be calibrated and the supplier must be able to document how the measurements are quality assured in accordance with the standards referred to in the previous point (5.1).

5.3 Instructions on how to use the measurement equipment must be included with the equipment in order that the measurements may be carried out according to the points in this chapter.

APPROACH TO STEP 1 MEASUREMENTS

5.4 Measurements must be carried out as long term measurements i.e. in the course of a period of a minimum of two months between the middle of October and the middle April. The measurement period may also be longer than two months. The longer the measurement period the more reliable the result.

5.5 As long as at least two months of the measurement period are between the middle of October and the middle of April, it may be accepted that a lesser part of the measurement period (up to 20%) is outside of the 6-month winter period.

5.6 The result of the measurement must be converted to the annual average radon level. With respect to buildings with balanced mechanical ventilation, the measured concentration of radon is set as equal to the annual average radon level multiplied by the seasonal correction factor 1.0 [5].

For buildings without balanced mechanical ventilation the annual average radon level is calculated using a seasonal correction factor of 1.0 or 0.75 depending when the measurement was performed. Please see the table under in addition to example 1.

Period	Factor
15^{th} – 31^{st} October	1.0
1^{st} November-31^{st} March	0,75
1^{st} April-15^{th} April	1,0

The calculation of a factor for a particular measurement period is shown in example 1.

Example 1: The calculation of the seasonal correction factor for the annual average radon level

- A measurement is carried out between the 10^{th} of February and the 15^{th} of April i.e. the measurement is performed for 64 days.
- 49 of the 64 days are in the period which has a seasonal correction factor of 0.75.
- 15 of the 64 days are in the period which has a seasonal correction factor of 1.0.

This gives the following conversion factor for the relevant measurement period.

$$\frac{(49 \cdot 0{,}75)}{64} + \frac{(15 \cdot 1)}{64} = 0{,}81$$

5.7 Measurements must be carried out in a frequently occupied rooms (defined in chapter 4).

5.8 Measurements must be carried out in all buildings and annexes with frequently occupied rooms.

5.9 Measurements must be performed in frequently occupied rooms on all of the floors which are in contact with the ground. This includes rooms on the ground floor and possible rooms in the basement where the floor or the wall of the room is in contact with the ground. At least one measurement per 150 square meter base area must be carried out on each floor where measurements are performed. At least three measurements must be carried out in each building. The measurements must be evenly divided. Prioritize frequently occupied rooms which may be particularly susceptible to radon supply, for example rooms with poor ventilation or rooms which are close to stairs, elevator shafts or pipe penetrations from the foundation.

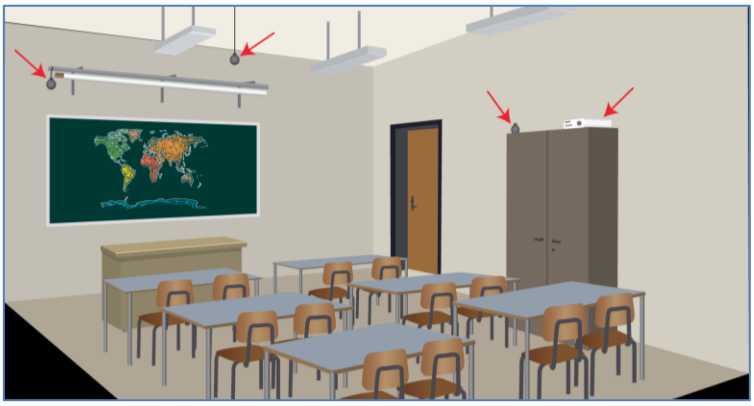
5.10 Determine whether or not there is a need for further measurements in rooms which are located on higher floors of the building. This may be necessary in the case of a building which is located in an area which is particularly susceptible to radon and where high levels of radon have been previously shown. In some cases the structural conditions of the building may provide an indication as to whether or not such measurements should be carried out.

5.11 Place measurement devices approximately 1-2 meters above the ground in order that they measure the air which is most representative for the air that one breathes in. In the room measurement devices should not be placed closer than approximately 20 cm to walls and corners and approximately 1.5 meters to doors, windows, air valves, heaters, radiators and other strong sources of heat (see example 2).

5.12 Measuring devices must lie or hang freely. The devices must not be moved but lie undisturbed in the same room during the course of the measurement period. Those using the building while a measurement is been carried out should be informed.

5.13 During the measurement period the building should be used and operated as usual with respect to ventilation, airing and heating.

Example 2: Placement of the measurement devices



Measurement devices can be placed on the teachers' desk. Alternatively etched track detectors in step 1 measurements can be hung on a cord or placed on the top of a cupboard. On the top of a cupboard is also suitable for measurement devices in step 2 measurements.

EVALUATION OF STEP 1 MEASUREMENTS

5.14 If the annual average radon level in all of the rooms where radon has been measured, is under the action level of 100 Bq/m^3, then it is unnecessary for follow up measurements.

5.15 If the radon level in one or more of the frequently occupied rooms is higher than 100 Bq/m^3, then one of the following measures should be carried out:

- A follow up step 2 measurement is carried out. This is performed in order to determine the actual radon concentration during kindergarten/school hours (see chapter 6).

- Implementation of permanent mitigation measures in order to reduce radon levels. These mitigation measures are followed up with new radon measurements. You can read more about radon mitigation measures on NRPAs website: https://www.nrpa.no/en/radon

6. STEP 2: FOLLOW UP MEASUREMENTS

REQUIREMENTS FOR MEASURING DEVICES

6.1 Follow up measurements must be performed using electronic measuring devices which can register radon levels at least once an hour. Documented routines for quality assured measurements in accordance with ISO 11665-5 [8] must be referred to.

APPROACH TO STEP 2 MEASUREMENTS

6.2 Step two measurements must be performed over a continuous period of at least three days during which time the building is used as normal. A longer measurement period, for example a week, will give a more reliable result.

6.3 Measurements should be carried out in every room where the radon levels in the step 1 measurement were over the action level of 100 Bq/m^3. If there were a large number of rooms in the same building, with a radon concentration over 100 Bq/m^3, it may be sufficient to measure radon in a selection of these rooms. In this case it is wise to prioritize the rooms with the highest levels of radon. In buildings with several ventilations systems, the step two measurements should be performed in the rooms associated with each individual system.

6.4 During the measurement period the building should be used and operated as usual with respect to ventilation, airing and heating. Those using the building should be informed that measurements are being carried out.

EVALUATION OF STEP 2 MEASUREMENTS

6.5 The average level of radon in the building during kindergarten/school hours is calculated for each of the frequently occupied rooms using the formula adopted from The Minister of Health in Canada [9]:

$$Rn_{school hours} = Rn_{step1} \times \frac{Rn_{step2, school hours}}{Rn_{step2,\ entire\ measurement\ period}}$$

$Rn_{school\ hours}$ is the calculated average level of radon in the room during kindergarten/school hours.

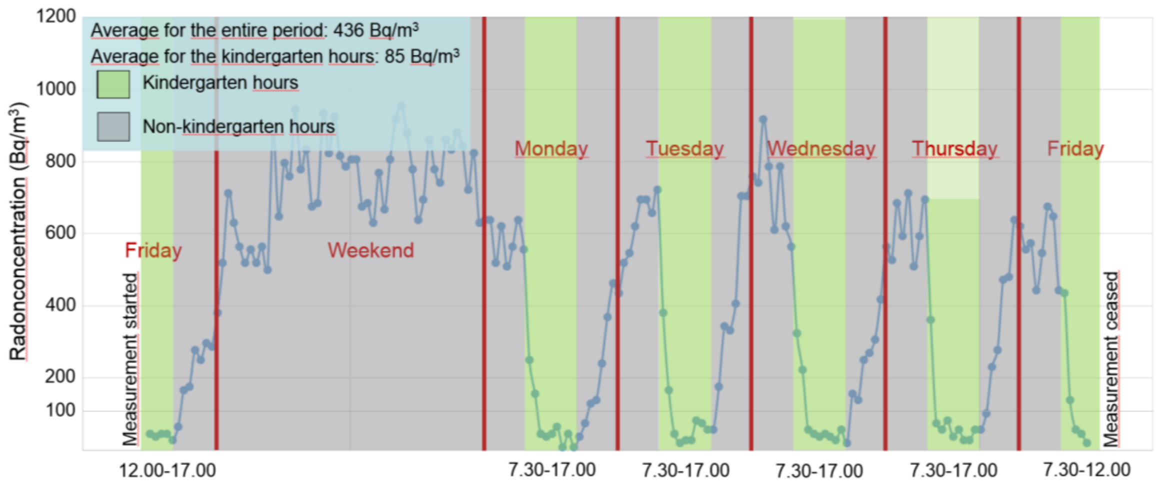
Rn_{step1} is the calculated annual average radon concentration from the step 1 measurements
$Rn_{step2,\ school\ hours}$ is the average radon concentration for the kindergarten/school hours during the step 2 measurement.
$Rn_{step\ 2,\ entire\ measurement\ period}$ is the average radon concentration for the entire measurement period in the step 2 measurement.

The average radon levels in kindergarten/ school hours ($Rn_{school\ hours}$) are calculated and this value must be compared to the limit value, see example 3.
If the radon concentration from the step 1 measurements ($Rn_{step\ 1}$) is more than twice as high as the radon concentration for the entire measurement period in the step 2 measurements, ($Rn_{step\ 2,\ entire\ measurement\ period}$), then the average radon levels in kindergarten/school hours cannot be calculated using the equation above. A new step 2 measurement is therefore necessary.

Example 3: Interpretation of the measurement results

A kindergarten has carried out radon measurements. The investigative step 1 measurements were over 100 Bq/m³. The kindergarten has ventilation which is on during kindergarten hours i.e. from 7.30 am to 5.00 pm.

Step 1 measurements showed that the radon levels were at their highest in the playroom. Here the levels were 480 Bq/m³. In order to investigate how the ventilation affects the radon level, a follow up step 2 measurement was carried out. The step 2 measurement was carried out in the course of a week, from a Friday to a Friday.



The follow up step 2 measurements showed that the radon concentration varied in the course of a twenty four hour period, depending on whether or not the ventilation was on. The average radon concentration for the entire measurement period was 436 Bq/m³. However during kindergarten hours the average was 85 Bq/m³.

Given that the average for the entire step 2 measurement period is not so much lower than the value from the step 1 measurement, the step 2 measurement may be seen as representative. The radon level during kindergarten hours may be calculated as follows:

$$Rn_{schoolhours} = Rn_{step1} \times \frac{Rn_{step2,schoolhours}}{Rn_{step2,entire\ measurement\ period}} = 480\ Bq/m^3 \times \frac{85\ Bq/m^3}{436\ Bq/m^3} = \underline{\underline{94\ Bq/m^3}}$$

The limits for radon – action level (100 Bq/m³) and limit level (200 Bq/m³), are valid for the radon levels in the building during kindergarten hours. The calculated radon level during kindergarten hours was 94 Bq/m³ and shows that the requirements are complied with. Given that it usually takes time for the ventilation system to reduce the levels of radon, the kindergarten has decided to start the ventilation an hour earlier. In this way the level of radon may be further reduced during kindergarten hours.

7. MEASUREMENT REPORT

7.1 A measurement report is a documentation of the measurement. The report may be prepared for both step 1 and step 2 measurements, either separately or combined

7.2 A measurement report should contain the following information:

- Information about the fact that the measurement is carried out in accordance with NRPAs' *Protocol for radon measurement in schools and kindergartens 2015,* possible deviation from the measurement protocol as well as the reason behind the deviation.
- The assigner's name and address.
- The address of the building where the measurement was carried out.
- Information about the measuring device which was used.
- For each of the rooms in which radon was measured, the report must contain:
  - ✓ The particular type of measuring device used including the serial number which may be used to identify it.
  - ✓ The type of room in which radon was measured. The room may be identified by number or another form of identification.
  - ✓ The dates for which the measurement started and ceased.
  - ✓ Radon concentrations and the annual average radon concentrations must be given in Bq/m^3 as well as the measurement uncertainty in accordance with The ISO/IEC Guide 98-3 [10]. Measurement uncertainty should be calculated using a coverage factor of 1 and 2 for step 2 and step 1 measurements respectively.
  - ✓ The type of ventilation.
- Measured or calculated radon levels (defined in point 6.5) in kindergarten/school hours.
- Measurement results, which are under the Minimum Detectable Activity (MDA), should be reported as less than this value. (For example if the MDA is 10 Bq/m^3 any results less than this value should be reported as < 10 Bq/m^3.)
- The date for when the report was finished as well as information regarding who finished it.
- The following or equivalent information from NRPA

Radiation Protection and Use of Radiation Act sets certain requirements to radon levels in kindergartens, primary and secondary schools. This includes both public and private kindergartens and schools. The levels of radon must be as low as reasonably practicable and the annual average radon levels should be below the limit value of 200 Bq/m^3 in frequently occupied rooms. In the event of radon levels exceeding the action level of 100 Bq/m^3 in a frequently occupied room, radon mitigation measures must be put in place.

Read more on NRPA's website http://www.nrpa.no/en/radon

APPENDIX: BACKGROUND TO THE PROTOCOL

STEP 1: INVESTIGATIVE MEASUREMENTS

A5.1 There are two main types of etched track detectors – open and closed. The closed etched track detectors are the most frequently used and measure radon concentration directly. The open etched track detectors are continuously exposed to radon and radon daughters, which are present in the air. The measurement result will therefore be influenced by factors such as ventilation and the number of particles in the air.

A5.4 In the period 2013-2014 a survey of radon in Norwegian schools and kindergartens was carried out. This survey is summarized in the technical document “Seasonal variations in radon in schools and kindergartens with balanced mechanical ventilation” (in Norwegian) [5]. The results show that uncertainty in the measurements is less likely when the measurements are performed during the winter season. The report also shows that more reliable results are obtained from measurements which are carried out for more than a period of two months.

A5.5 The measurement season for radon is from the middle of October to the middle of April. The protocol permits that 20% of the measurement may be performed outside of the measurement season provided that at least two months of the measurement period is within the measurement season. See example 4.

Example 4: Measurements outside of the measurement season

A step 1 measurement is performed in the period 15th February to 15th May, a measurement period of 89 days in total. 34% (30 days) of the measurement was carried out outside the measurement season. The permitted limit is 20 % and the measurement does therefore not fulfill the requirements stipulated in this protocol. The measurement must therefore be discarded.

A5.6 The results from the survey carried out in 2013-2014 [5] show that seasonal variations are small in schools and kindergartens with balanced mechanical ventilation compared to Norwegian dwellings. The seasonal correction factor for these schools has therefore been altered from 0.75 to factor 1.0.

A5.7 It is the radon levels in frequently occupied rooms which contribute to radon exposure. It is therefore very important to have low radon concentrations in these rooms. It is irrelevant to compare additional measurements which are performed in rooms which are not frequently occupied, for example toilets, booths, storage rooms or technical rooms, with the limit value. These kinds of measurements may however be of interest when radon mitigation measures have to be implemented in order to reduce radon levels.

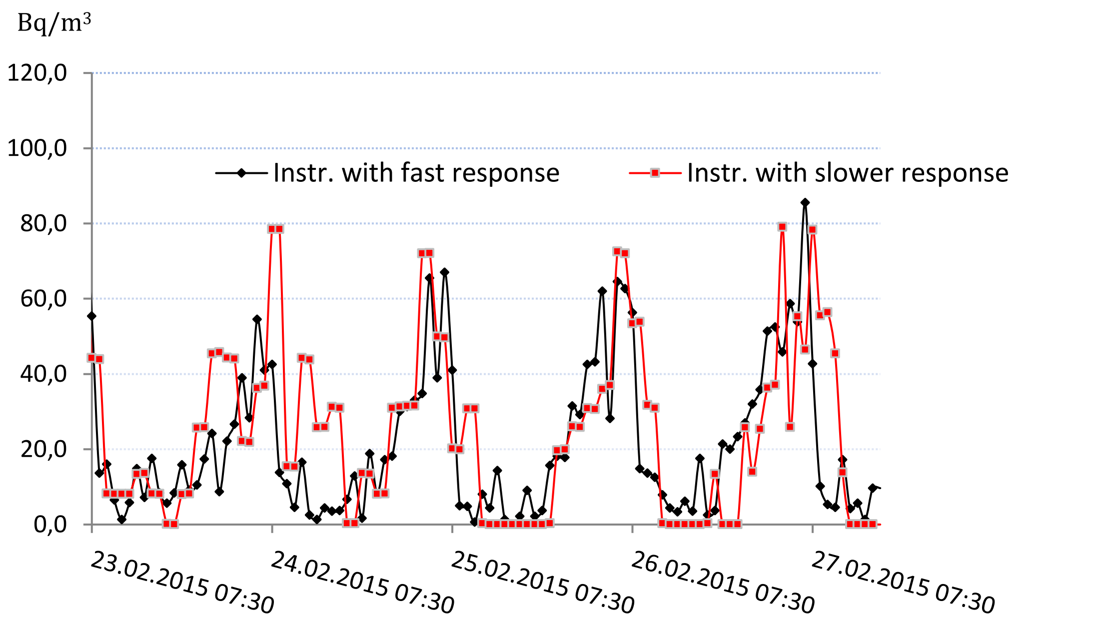
A5.8 If there are several annexes which are integrated in the building, there may be different levels of radon in these annexes. This can depend on the way in which the building was built, construction aggregates under the building etc.

A5.9 The greater the number of frequently occupied rooms that are measured, the better the overview of the radon situation in the building. The number of measurement points is however also a question of money. Statistical analysis of measurements performed in Oslo schools [10] show that the number of measurements could have been reduced by 66% without there being any significant differences in the number of school buildings where high concentrations of radon were determined. In Oslo schools an average of 1.2 measurements per 100 square meter ground plan were carried out. The minimum requirement of at least one measurement per 150 square meter base area is based on a general assessment.

A5.11 Optimal placement of measurement devices is usually in the middle of the room. However there are often practical reasons as to why this is not always possible. In order to ensure that the measurement is as representative as possible, it is important that it is the air that one inhales which is measured. A measurement should be carried out in a place with no drafts and little air flows. A measurement carried out near an air valve will often give a measurement result which is too low. This is due to the fact that the measurement will be influenced by the outdoor air supply which has low radon levels. Similarly a measurement carried out too close to a wall or a floor will often give a result which is too high. This is due to the fact that radon typically enters buildings through cracks in the floor or wall. Furthermore building materials made of stone, for example concrete walls, are capable of releasing radon which results in higher radon levels just by the walls than there otherwise is in the rest of the room.

A6.1 Step 2 measurements are carried out in order to determine the extent to which the buildings ventilation system reduces radon concentration in actual kindergarten/school hours. Instruments may have different levels of sensitivity. How quickly radon levels fall after the ventilation is turned on in the morning, will be seen differently from one instrument to another. Some instruments have shorter response time than others. This is due to the fact that the air is pumped into the measurement chamber. However in other instruments the air diffuses in and therefore the response time is slower. Example 5 shows radon concentration measured with two different instruments. The black graph shows data from an instrument with a rapid response, while the red graph shows data from an instrument with a slower response.

Example 5: Graphs which show two instruments with different responses



Instruments with slower response will usually measure higher radon concentrations in the morning and lower values when the ventilation is turned off in the afternoon. It is the average value in kindergarten/school hours which is important. In the example above both of the instruments show radon levels under the action level – 12 Bq/m³ (fast response) and 22 Bq/m³ (slower response). For information about a specific measurement device, you need to read the instruction manual or contact the manufacturer or importer.

A6.2 Given that short term variations dominate in buildings with balanced mechanical ventilation, will a measurement carried out over several days give the best result. If the measurement device logs radon concentration once an hour, than eight values may potentially be registered in the course of a day. The more days the measurement is carried out, the less uncertain the measurement result will be. It is important to be aware of the fact that radon levels are usually highest Monday morning. This is due to the fact that the radon concentration has built up over the weekend when the ventilation has been operating at reduced capacity.

A6.5 Given that the step 2 measurements are performed in the course of a few days, they are not necessarily representative of the annual average concentration. However step 1 measurements can be used to correct the value obtained in step 2 measurements and the radon levels in kindergarten/school hours may subsequently be calculated [11]. If the radon concentration from the step 1 measurement is much higher than the radon concentration for the entire step 2 measurement period, it may suggest that the ventilation alone is not sufficient to reduce the daytime radon levels. The reason may however also be natural variation and little inflow of radon due to different measurement periods. A step 2 measurement carried out continuously in the course of a week will give a radon concentration for the whole measurement period which is more similar to the result from the step 1 measurement.

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