



## **EAN Working Group on the Application of ALARA for Radon At Work (A-RAW)**

### **Why a Survey on radon?**

National regulations for the protection against radon at the workplace have recently evolved in Europe. In general, the number of workplaces affected by the regulations has increased; including many workplaces not previously aware of the radiation protection system. Furthermore, the practical application of the regulation for radon, using a step-by-step approaches, with reference level/exposure values, might be challenging in practice. It can raise questions from employers and other affected parties and communication might be an issue

As a consequence, the European ALARA Network has set up, in 2021, a working group to investigate the practical implementation of the ALARA principle in relation to exposure from Radon At the Workplace (A-RAW).

### **The objective**

The objective of the working group is to collate a sample of practical experiences in Europe (1~2 case studies per country), detailing the controls and measures implemented to protect against radon exposure in the workplace.

A set of questions to assist the description of suitable case studies is proposed (cf. below). It focuses on the steps taken to identify and manage workplaces with regard to radon.

The Working Group aims to synthesize the experiences collected from the field

1. Commonalities and differences
2. Lessons-learned,
3. good practices and difficulties in application.

These information can be useful to discuss the application of ALARA principle in these situations, address potential gaps and identify if actions (ex. guidance) are needed in the future and by who.

The Working Group aims to share these results to the concerned radiation protection community and will work on identifying opportunities to do so.



**SET OF QUESTIONS.**

**1 survey = 1 case study of your choice** (workplace concerned with regulation on radon: touristic cave, underground workplace, bakery, robot factory ...)

The check box (; ) are used to have a quick view of the national regulation. The text inbox host experience from the practical case study.

<b>ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY</b>
<p><b>Could you please provide a short description of the case study and the workplace?</b> Context, sitting, number of workers etc. ...</p>
<b># IDENTIFICATION OF WORKPLACES</b> Context: Radon measurements shall be carried out in identified workplaces
<ul style="list-style-type: none"> <li>• <b>What are the criteria to select the workplaces?</b> <input type="checkbox"/> Workplace in basement <input type="checkbox"/> Workplace in ground floor <input type="checkbox"/> Map or radon-prone area <input type="checkbox"/> Specific workplace <input type="checkbox"/> former radon measurement <input type="checkbox"/> other: ...</li> <li>• <b>Using the criteria:</b> <input type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> </ul>
<p><b>What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?</b> ...</p>
<b># RADON CONCENTRATION MEASUREMENT</b> Context: Radon measurement protocol.
<ul style="list-style-type: none"> <li>• <b>Normative protocol for radon concentration measurement</b> <input type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Preference given to</b> <input type="checkbox"/> passive or <input type="checkbox"/> direct-reading measurement devices?</li> <li>• <b>Accredited/certified services for radon concentration measurements</b> <input type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Are provisions for verification measurement provided in law?</b> <input type="checkbox"/> Yes <input type="checkbox"/> No</li> </ul>
<p><b>What are your views about the protocol for radon concentration measurement?</b> Issues in practicality, cost, information to the workers and/or Health and Safety ...</p>
<p><b>What if &lt; reference level?</b> Any (mandatory) requirements to reduce exposure ALARA? ...</p>
<b># DIAGNOSIS AND REMEDIATION</b> Context: If > reference level, remedial action to reduce radon concentration shall be taken.
<ul style="list-style-type: none"> <li>• <b>Who is responsible?</b> <input type="checkbox"/> Employer <input type="checkbox"/> Property Owner</li> <li>• <b>Are accredited/certified services for radon concentration measurements mandatory?</b> <input type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Are guidance available to help establish a diagnosis of the building and inform the</b></li> </ul>



**type of mitigation required?**  Yes  No  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*

- **Is it needed?**  Yes  No
- **Time frame for remediation actions?** ... (years)
- **Time frame for remediation follow-up measurement?** ... (years)
- **Same protocol as initial measurement?**  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**  
 Cost-efficacy consideration, numerical target, involvement of workers, ...  
 ...

**# GOING FURTHER**  
 Context: Remedial action were not sufficient.

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes  No
- **Who can perform the exposure assessment**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes  No  
*Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.*
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**  
 ...

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  Yes  No
- **Who is responsible of implementing the requirements?**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning) .....  Yes  No
  - Signage or warning system .....  Yes  No
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)? .....  Yes  No
  - Control of exposure of workers .....  Yes  No
  - Provision to "promote the development of an appropriate radiation protection culture" by the workers .....  Yes  No
  - Re-measurement/re-assessment .....  Yes  No
  - Other: ...

**Any details you would like to report?**  
 ...

**# CASE WHERE EFFECTIVE DOSE ≥ 6 mSv**



- **Who is responsible for the implementation of licencing requirements for the workers?**  *Employer*  *Property Owner*

- **Are there practical difficulties in?**

- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.) .....  Yes  No
- Categorization of workers? .....  Yes  No
- Recording and reporting of result (dose register) and access to the results? .....  Yes  No
- Protection of outside workers? .....  Yes  No
- How do employers access/obtain advice from a radiation protection expert and training and education in radon .....  Yes  No
- Other: ...

**Any details you would like to report?**

...

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

...

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Belgium.

### Case Study BE: Show caves

The check box () are used to have a quick view of the regulation. The text inbox host experience from the practical case study.

ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY
<p><b>Could you please provide a short description of the case study and the workplace?</b> <i>Show caves are of concern from a radiation protection point of view due to the high concentration of radon that can be present inside the caves and that can give rise to an enhanced exposure of the guides and maintenance workers. Show caves, accessible to the public and considered as a workplace for guides and maintenance workers are explicitly addresses as specific workplaces where an assessment of the radon exposure of the workers is mandatory in the national <a href="#">radon action plan</a>, (RAP §5.3.1) and in the guidance (<a href="#">link</a>), following the Royal Decree 20 July 2001 ( RD 2001, RP regulations) in <a href="#">article 4</a> and <a href="#">article 70/1.3</a>.</i></p> <p><i>If the reference level inside a show cave is exceeded, the employer is required to make a notification of the situation of existing exposure in the frame of professional activities involving natural sources of radiation (<a href="#">article 4</a> and <a href="#">article 9</a> of RD 2001, as part of the graded approach in the licencing process). Based on the notification, the employer will be required to carry out corrective measures. The corrective measures aim at reducing ALARA the exposure of the workers, namely the guides and the maintenance workers by carrying out a risk analysis calculating the different exposure scenarios of the employees. This requires generally a measurement campaign in the show cave using continuous radon monitoring or personal radon monitoring of the guides and workers. Guidelines are published on the FANC website (<a href="#">link</a>).</i></p> <p><i>In the specific case of show caves, actual remediation Interventions such as Increasing ventilation or Isolating the source are not feasible due to the nature of the environment where the Introduction of mechanical ventilation can not be justified due to the possible negative Impact on the cave atmosphere. In this case, the optimisation of the protection Is achieved by reducing the exposure of the workers based on a study of the annual variations of radon concentrations and the time-tables of the workers. In general, the exposure time of the workers can be adapted/organised In such a way that they remain below the limit of exposure of 600 000 Bq/m<sup>3</sup> or 6 mSv/y (RD 2001, <a href="#">article 20.3</a>).</i></p>
<p style="text-align: center;"><b># IDENTIFICATION OF WORKPLACES</b></p> <p style="text-align: center;">Context: Radon measurements shall be carried out in identified workplaces</p>
<ul style="list-style-type: none"><li>• <b>What are the criteria to select the workplaces?</b> <input type="checkbox"/> Workplace in basement <input type="checkbox"/> Workplace in ground floor <input type="checkbox"/> Map or radon-prone area <input checked="" type="checkbox"/> Specific workplace <input type="checkbox"/> former radon measurement <input type="checkbox"/> other: ...</li><li>• <b>Using the criteria:</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li></ul>
<p><b>What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?</b> Identifying the show caves on the territory Is done through organisation of speleologists and</p>

touristic Information channels. The responsible organisation is contacted and a work plan is agreed upon, assessing the concentration and variation of concentration inside the caves.

### # RADON CONCENTRATION MEASUREMENT

Context: Radon measurement protocol.

- **Normative protocol for radon concentration measurement**  Mandatory  Not mandatory
- **Preference given to**  passive or  direct-reading measurement devices?
- **Accredited/certified services for radon concentration measurements**  Mandatory  Not mandatory
- **Are provisions for verification measurement provided in law?**  Yes  No

#### What are your views about the protocol for radon concentration measurement?

Issues in practicality, cost, information to the workers and/or Health and Safety

Applying/requiring radon measurements in environments with little or no experience in radiation protection issues is a challenge and needs clear and easy-accessible guidance. This is done by providing detailed information and [guidance](#)

#### What if < reference level? Any (mandatory) requirements to reduce exposure ALARA?

In this specific case, the ALARA principle is applied by identifying if and how the exposed worker can organise their work in order to reduce their exposure to radon. In practice, it can be difficult in some cases with relatively high radon concentrations inside the caves to justify important reduction in working time spent in the cave if the worker is already below the reference level.

Active monitoring with personal radon detectors of the guides can be used as a tool for optimisation.

### # DIAGNOSIS AND REMEDIATION

Context: If > reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?**  Employer  Property Owner
- **Are accredited/certified services for radon diagnostic/remediation mandatory?**  Mandatory  Not mandatory
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  Yes  No  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*
- **Is it needed?**  Yes  No
- **Time frame for remediation actions?** 0.5 (years)
- **Time frame for remediation follow-up measurement?** 1 (years)
- **Same protocol as initial measurement?**  Yes  No

#### Is the optimization principle considered in the implementation of the remedial action?

The remedial action in this case study is never an intervention in terms of physical work, but always an assessment of the exposure of the worker with an optimisation of this exposure by controlling the working time.

### # GOING FURTHER

Context: Remedial action were not sufficient.

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes  No
- **Who can perform the exposure assessment**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes  No  
*Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.*
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**

Notification (declaration) to FANC is needed (RD 2001, [article 9](#)), reporting the measurement results and the exposure assessment, after which corrective actions are required, followed by control measures and eventually an inspection. A specific advantage in this case is that the exposure of the workers can be assessed in terms of radon exposure (with a limit of 600 kBq/m<sup>3</sup> per year) or by dose assessment (6 mSv per year, RD 2001 [article 20.3](#)), allowing a better protection of the workers, since 600 kBq/m<sup>3</sup> is in all scenario's less than 6 mSv/y, easier to assess, and directly related to the reference level of 300 Bq/m<sup>3</sup> (for a full-time working year of 2000h). As for the exposure in caves, measurements of aerosol concentration and radon progeny could refine the dose assessment of the workers. Until now, this has not been implemented due to the complexity (and cost) as well as uncertainty (temporal and spatial variations) of such studies/assessments.

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  Yes  No
- **Who is responsible of implementing the requirements?**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning)  Yes  No  
.....
  - Signage or warning system  Yes  No  
.....
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)?  Yes  No  
.....
  - Control of exposure of workers  Yes  No  
.....
  - Provision to "promote the development of an appropriate radiation protection culture" by the workers  Yes  No  
.....
  - Re-measurement/re-assessment  Yes  No  
.....



- Other: ...

**Any details you would like to report?**

Signage or warning systems are not easily accepted by the employer, since they are not mandatory by regulations. Continuous radon measurements in each show cave is always recommended, but only obligatory if the declaration and assessment shows that the exposure of the workers is likely to exceed the reference levels. The radiation protection culture among the workers is not always easy due to the lack of knowledge or interest in the subject (perception by the workers of radon as an unidentifiable (for them) and 'natural' source of a 'statistical' risk). The turn-over of personnel also complicates to continuity of the follow-up surveillance systems.

**# CASE WHERE EFFECTIVE DOSE  $\geq$  6 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  Employer  Property Owner

- **Are there practical difficulties in?**

- Individual radiological surveillance: dosimetry system

(calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.)

Yes  No

.....

- Categorization of workers?

Yes  No

.....

- Recording and reporting of result (dose register) and access to the results?

Yes  No

.....

- Protection of outside workers?

Yes  No

.....

- How do employers access/obtain advice from a radiation protection expert and training and education in radon

Yes  No

.....

- Other: ...

**Any details you would like to report?**

Declaration and follow up is mandatory and organised in the frame of RD 2001 [article 9](#).

Theoretically, the work activity could be submitted to licencing if the situation does not allow to guarantee the exposure of the workers to remain below 600 000 Bq/m<sup>3</sup> or 6 mSv/y (RD 2001, [article 20.3](#).)

In the case of show caves it is likely to happen in the case where the radon concentrations would be too high to guarantee the exposure of the guides to remain below the annual limits without impacting the economic consequences (number of hours worked) for the worker too

much.

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

This is not applicable for the case study of show caves.

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## Case Study BE: Waterworks

The check box () are used to have a quick view of the regulation. The text inbox host experience from the practical case study.

### ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY

#### Could you please provide a short description of the case study and the workplace?

Waterworks, and especially pumping stations of groundwater for drinking water production, are of concern from a radiation protection point of view due to the emanation of radon from the groundwater into the indoor air of the building. Besides this, there can be concern of retention and concentration of Ra-226 in the filtration system. Waterworks are explicitly addresses as specific workplaces where an assessment of the radon exposure of the workers is mandatory in the national [radon action plan](#), (RAP §5.3.1) and in the guidance ([link](#)), following the Royal Decree 20 July 2001 ( RD 2001, RP regulations) in [article 4](#) and [article 70/1.3](#).

If the reference level for a specific waterwork is exceeded, the employer is required to make a notification of the situation of existing exposure in the frame of professional activities involving natural sources of radiation ([article 4](#) and [article 9](#) of RD 2001, as part of the graded approach in the licencing process). Based on the notification, the employer will be required to carry out corrective measures, either directly by reducing the radon concentration (interventions in terms of ventilation, mechanical controlled ventilation systems, etc.), or through an intermediate step by carrying out a risk analysis calculating the different exposure scenarios of the employees. This requires generally a measurement campaign in the workplace premises by active and continuous radon monitors. Guidelines are published on the FANC website ([link](#)).

Waterworks (as workplaces listed in RAP §5.1.3) are submitted to an inspection program by FANC (the RP competent authority). The inspection includes control measures in which the effectiveness of the corrective measures and the compliance of the exposure of the workers is assessed.

Theoretically, the work activity could be submitted to licencing If the situation does not allow to guarantee the exposure of the workers to remain below 600 000 Bq/m<sup>3</sup> or 6 mSv/y (RD 2001, [article 20.3](#)).

In the case of waterworks, either the building can be mitigated by installing and active ventilation system or by providing sufficient passive ventilation, either an exposure assessment of the workers can proof they are well below the exposure limit.

#### # IDENTIFICATION OF WORKPLACES

Context: Radon measurements shall be carried out in identified workplaces

- **What are the criteria to select the workplaces?**

Workplace in basement  Workplace in ground floor  Map or radon-prone area  Specific workplace  former radon measurement  other: ...

- **Using the criteria:**  Mandatory  Not mandatory

**What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?**

In general, the most relevant type of workplaces can be Identified in terms of number of exposed workers, level of potential exposure en collective or individual impact. This can be used to prioritise or Intensify the assessment of the exposure In these specific workplaces because of the bigger risk, In the framework of a graded approach.

Fore the case study, identifying and contacting the employers responsible for the waterworks is done trough consultation of umbrella bodies such as professional associations, regional water companies, local municipal water companies, etc.

**# RADON CONCENTRATION MEASUREMENT**

Context: Radon measurement protocol.

- **Normative protocol for radon concentration measurement**  Mandatory  Not mandatory
- **Preference given to**  passive or  direct-reading measurement devices?
- **Accredited/certified services for radon concentration measurements**  Mandatory  Not mandatory
- **Are provisions for verification measurement provided in law?**  Yes  No

**What are your views about the protocol for radon concentration measurement?**

Issues in practicality, cost, information to the workers and/or Health and Safety

Applying/requiring radon measurements in environments with little or no experience in radiation protection issues is a challenge and needs clear and easy-accessible guidance. This is done by provided detailed information and [guidance](#)

**What if < reference level?** Any (mandatory) requirements to reduce exposure ALARA?

In this specific case, the ALARA principle is applied by identifying good practises to keep the exposure of the workers during maintenance practises as low as possible by determining the optimised ventilation procedure of the specific building. Typically, active radon monitoring can give information on the time needed to keep the doors open before accessing the building in order to reduce the radon concentration inside the building below the reference level (300 Bq/m<sup>3</sup>). The workers are than asked to wait for this time period (which is usually in the order of 15-25 minutes) before accessing the building and start the maintenance work.

**# DIAGNOSIS AND REMEDIATION**

Context: If > reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?**  Employer  Property Owner
- **Are accredited/certified services for radon diagnostic/remediation mandatory?**  Mandatory  Not mandatory
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  Yes  No  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*
- **Is it needed?**  Yes  No

- Time frame for remediation actions? 0.5 (years)
- Time frame for remediation follow-up measurement? 1 (years)
- Same protocol as initial measurement?  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**

Cost-efficacy consideration, numerical target, involvement of workers, ...

Yes, the possibilities for remedial actions in the case of waterworks are generally limited to improving ventilation. Following the long-term monitoring, a procedure for additional ventilation during and before the maintenance work is aimed at optimising the protection of the workers.

**# GOING FURTHER**

Context: Remedial action were not sufficient.

- Is it clear how to notify the situation to the competent authority?  Yes  No
- Is then the exposure assessment always requested?  Yes  No
- Who can perform the exposure assessment  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?  Yes  No  
*Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.*
- Is it needed?  Yes  No

**What are your views about the exposure assessment process?**

Notification (declaration) to FANC is needed (RD 2001, [article 9](#)), reporting the measurement results and the exposure assessment, after which corrective actions are required, followed by control measures and eventually an inspection. A specific advantage in this case is that the exposure of the workers can be assessed in terms of radon exposure (with a limit of 600 kBq/m<sup>3</sup> per year) or by dose assessment (6 mSv per year, RD 2001 [article 20.3](#)), allowing a better protection of the workers, since 600 kBq/m<sup>3</sup> is in all scenario's less than 6 mSv/y, easier to assess, and directly related to the reference level of 300 Bq/m<sup>3</sup> (for a full-time working year of 2000h).

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- Is it clear how to notify the results of the exposure assessment to the competent authority?  Yes  No
- Who is responsible of implementing the requirements?  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- Are there practical difficulties in?
  - The identification of radon prone area (zoning)  Yes  No
  - .....
  - Signage or warning system  Yes  No
  - .....
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)?  Yes  No

- .....
- Control of exposure of workers  Yes  No
- .....
- Provision to "promote the development of an appropriate radiation protection culture" by the workers  Yes  No
- .....
- Re-measurement/re-assessment  Yes  No
- .....
- Other: ...

**Any details you would like to report?**

Signage or warning systems are not easily accepted by the employer, since they are not mandatory by regulations. The control on the functioning and continuity of extraction fans is difficult to implement in practice. Continuous radon measurements in each pumping station is too expensive to implement, so the detailed follow up of the exposure of the workers is done by calculations based on measurement campaigns. The radiation protection culture among the workers is not always easy due to the lack of knowledge or interest in the subject (perception by the workers of radon as an unidentifiable (for them) and 'natural' source of a 'statistical' risk). The turn-over of personnel also complicates to continuity of the follow-up and maintenance of the remediation systems.

**# CASE WHERE EFFECTIVE DOSE  $\geq$  6 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  Employer  Property Owner
- **Are there practical difficulties in?**

- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.)  Yes  No
- .....
- Categorization of workers?  Yes  No
- .....
- Recording and reporting of result (dose register) and access to the results?  Yes  No
- .....
- Protection of outside workers?  Yes  No
- .....
- How do employers access/obtain advice from a radiation protection expert and training and education in radon  Yes  No
- .....
- Other: ...

**Any details you would like to report?**

Declaration and follow up is mandatory and organised in the frame of RD 2001 [article 9](#).

Theoretically, the work activity could be submitted to licencing If the situation does not allow to guarantee the exposure of the workers to remain below 600 000 Bq/m<sup>3</sup> or 6 mSv/y (RD 2001, [article 20.3](#).)

In the case of waterworks, either the building can be mitigated by installing an active ventilation system or by providing sufficient passive ventilation, either an exposure assessment of the workers can prove they are well below the exposure limit.

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

In the case of waterworks, the assessment and declaration can refer to three different radiation protection regulations: the content of natural radionuclides in the groundwater (producing drinking water), regulated by the directive [2013/51/EURATOM](#), the RP regulation [RD 31 May 2016](#) and the FANC Decree of [24/11/2016](#) and assessing Rn-222 maximum concentration in the drinking water of 100 Bq/L, the professional activities implying natural radiation sources (NORM) in case of contamination of filters and installations with Ra-226 and its descendants coming from the ground water (RD 2001, [Article 4](#), and the radon regulation framework discussed above. For this, a good coordination between the people involved in the three different aspects is needed, with a common approach on information campaigns, analysis and treatment of the declarations, and inspection programs.

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Switzerland.





# Radon at workplaces, Case Studies (Switzerland)

## 1. Legal provisions

### 1.1. Reference level and threshold value

The Swiss legislation on radiation protection has been revised and adapted in accordance with the new international recommendations and standards, in particular the ICRP 103 recommendations as well as the Euratom and IAEA basic safety standards. The "Radon Action Plan 2012-2020" integrates this objective of bringing the legal provisions for protection against radon into line, in particular by lowering the legal values.

According to article 155 of the Ordinance on Radiation Protection (RPO), which came into force on January 1, 2018, the reference level for the average annual concentration of radon gas in "premises where people regularly stay for several hours a day" is set at 300 Bq/m<sup>3</sup>. These are, for example, dwelling premises or ordinary workplaces located in buildings.

In addition to the reference level of 300 Bq/m<sup>3</sup>, a threshold value of 1000 Bq/m<sup>3</sup> is applicable for the annual concentration at workplaces exposed to radon (Art. 156 RPO). Radon-exposed workplaces are workplaces where the threshold value of 1000 Bq/m<sup>3</sup> is exceeded or suspected to be exceeded. These are, in particular, workplaces in underground installations, mines, caves and water supply installations, as well as those classified by the national radiation protection supervisory authorities (in particular Suva for trade and industry). These criteria for selecting radon-exposed workplaces do not differentiate between radon-prone areas and other areas and therefore do not take into account the potential for radon emission from the ground.

### 1.2. Radon measurements

According to article 165 of the RPO, companies with radon-exposed workplaces must ensure that radon measurements are carried out by an approved radon measurement service. The national authorities responsible for monitoring radon-exposed workplaces may carry out measurements by pointing. Case study 3 illustrates this situation.

In accordance with article 165 of the RPO, approved radon measurement services are required to use instruments that meet the requirements of the Ordinance on Measuring Instruments for Ionizing Radiation and, in particular, have been approved by the Federal Institute of Metrology (METAS). In addition, approved radon measurement services must follow prescribed measurement protocols and enter their results in the central radon database (Art. 160 RPO).

## **1.3. Actions to reduce radon exposure**

### **1.3.1. Ordinary workplace located in buildings**

According to article 166 of the RPO, if the reference level of 300 Bq/m<sup>3</sup> is exceeded at an ordinary workplace, the building owner is responsible for taking the necessary remediation measures at his own expense, according to the criteria for the urgency of the work set out in the "Radon Guidelines" of the Federal Office of Public Health (FOPH). To do so, the owner may call upon services of radon consultants. The list of services of radon consultants is published on the FOPH's Internet website, in accordance with article 161 of the RPO. If the owner remains inactive, the cantonal authorities can order a remediation (Art. 166 RPO). Case study 1 illustrates this situation.

### **1.3.2. Workplaces exposed to radon**

If the threshold value of 1000 Bq/m<sup>3</sup> is exceeded in a specific workplace, immediate measures must be taken. The enterprise must determine the annual radon-related effective dose to exposed persons with the help of an approved radon measurement service and review this at least every five years (Art. 167 RPO). This estimate takes into account the time spent each year by the worker(s) in the concerned workplace. If the effective dose of a person exceeds 10 mSv per year, the company must immediately take organisational (reduction of working time) or technical measures to reduce this dose. Case study 2 illustrates this issue.

If, despite the measures taken, the effective dose that a person may receive at her workplace is still greater than 10 mSv per year, the person is considered to be occupationally exposed to radiation worker (Art. 167 RPO). Consequently, the company is subject to licensing in accordance with article 9 of the RPO.

According to article 61 of the RPO, the dose received by occupationally exposed workers must be determined for each person individually, using an approved personal dosimetry service for radon. In cases where individual dosimetry is not appropriate, the agreement of the supervisory authority (Suva, FOPH) is required for the determination of the radiation dose by the licensee by calculation (Art. 62 RPO).

The method for determining the dose received by a worker exposed to radon is laid down in Annex 12 of the Dosimetry Ordinance, which entered into force on 1 January 2018. This method is based on the nominal risk coefficient for a worker's radon exposure from ICRP Publication 115 (2010), as well as the total risk coefficient for cancer and hereditary effects from ICRP Publication 103 (2007). For an equilibrium factor of the offspring of 1, the radon dose coefficient is 1,87.10<sup>-5</sup> mSv/Bqhm<sup>-3</sup> (or 11.9 mSv/WLM) for workers. According to appendix 1 of the Dosimetry Ordinance, the equilibrium factor is set at 0.4 by default. However, article 39 of the Dosimetry Ordinance allows the licensee to determine this factor himself by means of appropriate measurements and to apply it with the approval of the supervisory authority.

In the next few years, the FOPH will closely monitor the development of the state of the art at international level and, if necessary, adapt the Dosimetry Ordinance to the coefficients of ICRP Publication 137 (2017).

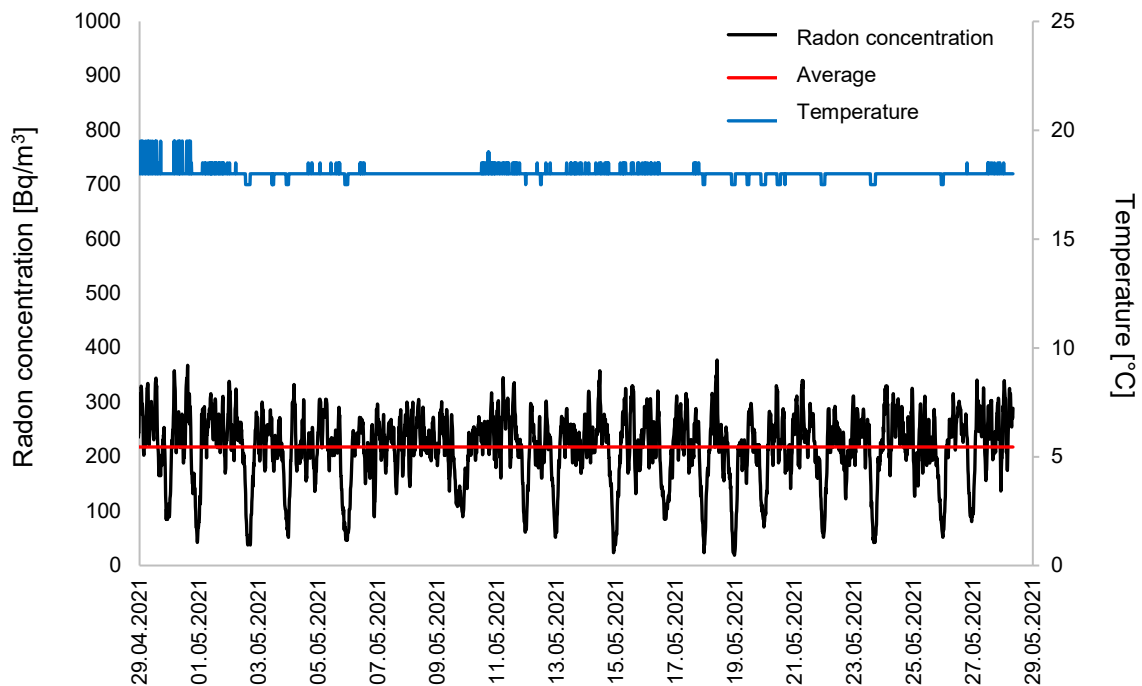
## 2. Experience feedback

### 2.1. Reference level exceeded (Case study 1)

An approved radon measurement service performed passive radon measurements in a company in 2020. The results indicated a concentration of 350 Bq/m<sup>3</sup> on average per year at a workstation located in the basement and occupied 2000 hours per year. The floor in question being equipped with an automated window opening system, the radon consultant in charge of the remediation proposed to the owner of the building to control the opening of the windows of the neighboring room (unoccupied and with the highest radon concentration of the floor) by means of a dedicated radon detector. On this detector, it was possible to set a threshold at which the window will open (Alarm Level) and to set the duration of each measurement, which also corresponds to the duration of the window opening (Sampling Interval). The following settings were used for the automatic opening of the windows for the system efficiency tests:

Measurement period [dates]	Alarm Level [Bq/m <sup>3</sup> ]	Sampling Interval [min]	Average radon [Bq/m <sup>3</sup> ]
26.04.2021 until 28.04.2021	250	30	185
28.04.2021 until 28.05.2021	300	15	220

The results (see graph 1) indicate that the average radon concentration remained below the reference level of 300 Bq/m<sup>3</sup> with the two automatic window opening parameters. The temperature in the room varied between 18.5°C and 19.5°C, despite periods of cold weather outside. The radon consultant has therefore installed the system permanently with 300 Bq/m<sup>3</sup> as "Alarm Level" and 15 minutes of "Sampling Interval". An approved passive measurement will then allow the system to be officially validated.

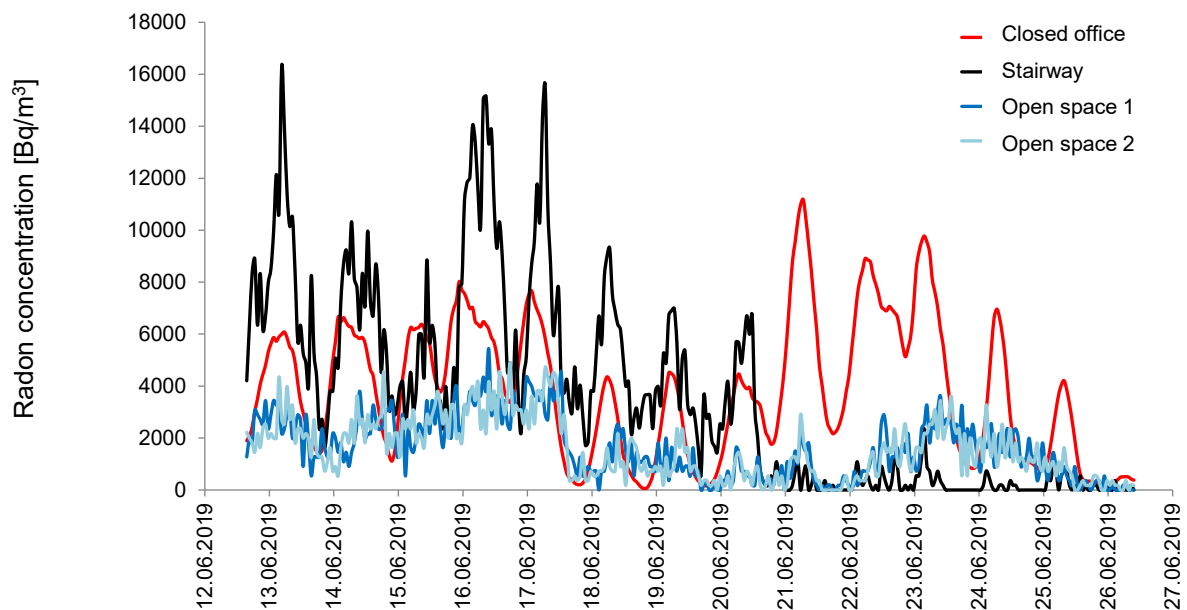


Graph 1: Radon concentration after remediation

## 2.2. Exceeding the threshold value (Case study 2)

Passive measurements were performed during the winter of 2018/2019 in an industrial building, with results indicating a concentration of approximately 2700 Bq/m<sup>3</sup> in an open space located on the first floor and occupied 2000 hours per year. This corresponds to an effective dose of approximately 40 mSv per year for the persons working in this open space.

The radon consultant, contracted for the remediation, performed short measurements during the summer of 2019. As shown in the graph 2 below, the open space was not the main location of radon infiltration. Maximum values above 10'000 Bq/m<sup>3</sup> were measured in the stairway and in a closed office, both located on either side of the open space.



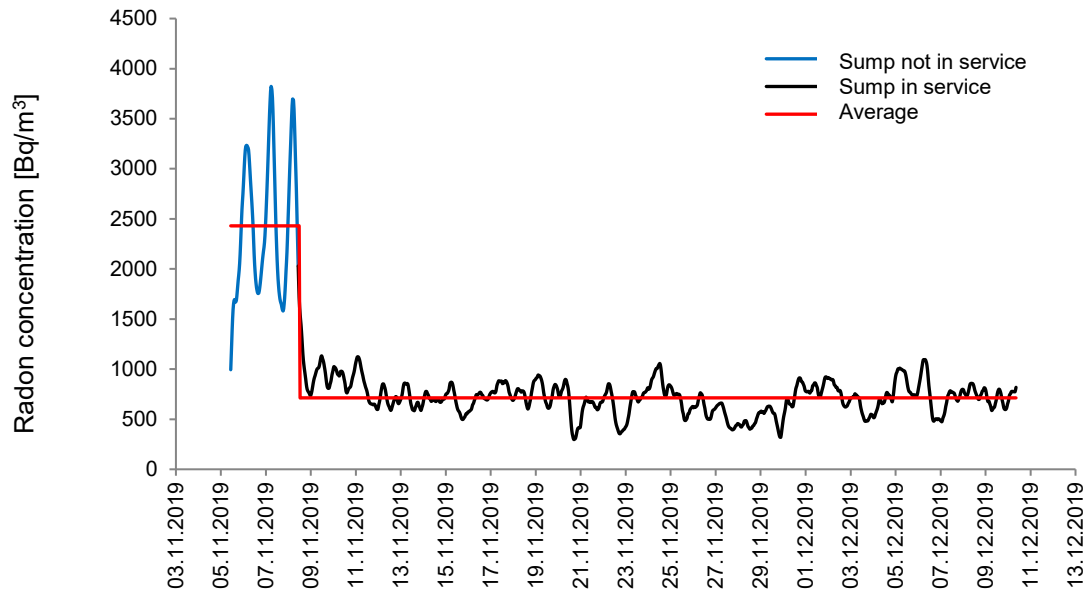
Graph 2: Radon concentration before remediation

Remedial measures (installation of two sumps, one under the closed office and one under the stairway) have been implemented (see picture 1).



Picture 1: Installation of one sump under the closed office (left) and another sump under the stairway (right)

The graph 3 below shows the effect of the installation of the sump under the closed office. This graph shows the results of a short measurement as indicative value. The decrease in radon concentration is clear, but it stabilizes at around 700 Bq/m<sup>3</sup>. Approved control measurements are currently underway to verify compliance with the threshold value of 1000 Bq/m<sup>3</sup> over one year and to clarify whether additional corrective actions need to be undertaken to achieve a radon concentration below the reference level of 300 Bq/m<sup>3</sup> in the workplaces (open space), in accordance with the ALARA principle.



Graph 3: Effect of the radon remediation in the closed office

### 2.3. Pilot measurements in water supply facilities (Case study 3)

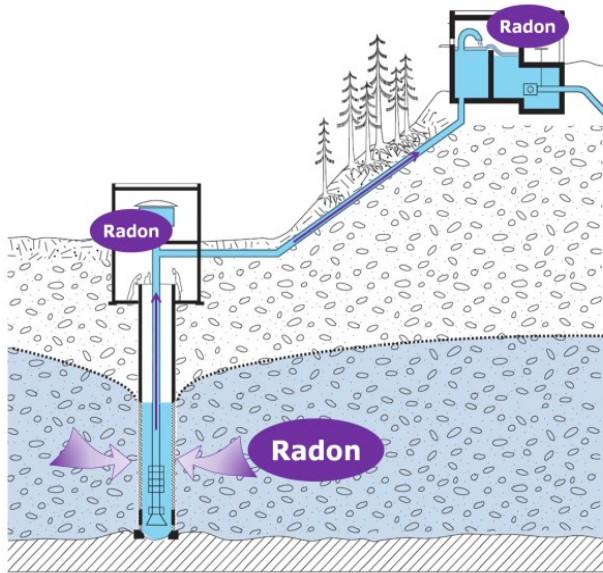
Suva, as the supervisory authority in the fields of trade and industry, measured nearly 200 water supply companies according to article 165 of the RPO. The aim of this campaign was to obtain a first global overview of the workers exposure in such facilities, which are categorised as radon-exposed workplaces according to article 156 of the RPO.

The measurement protocol for radon-exposed workplaces requires radon measurements with passive dosimeters for at least one month in summer and one month in winter.

The average annual radon concentrations measured were around 2200 Bq/m<sup>3</sup> for pumping stations, 2600 Bq/m<sup>3</sup> for water tanks and 13'000 Bq/m<sup>3</sup> for water catchments (see picture 2). Based on these values, the short exposure times and an equilibrium factor of 0.4, the average dose per worker was estimated to be around 6 mSv per year in the large majority of companies. Consequently, they will not be subject to licensing in accordance with article 9 of the RPO. However, as the threshold value is exceeded, the companies must review the annual radon-related effective dose to exposed persons at least every five years.

In 13 water supply companies, the average dose estimation per worker exceeded 10 mSv per year, taking into account the indicated exposure times. At present, a pilot individual dosimetry with passive dosimeter is being carried out on about 100 people working for these 13

companies or for 15 maintenance companies. Based on these results, Suva will decide whether organizational or technical measures are required for these specific companies according to ALARA principle, or whether a switch to the planned exposure situation is necessary, in which case the workers would be considered as occupationally exposed to radiation.



*Picture 2: pumping station and water tank (left), water catchment (right)*

It should also be noted that radon decay products accumulate in filters of dehumidifiers, ventilation or refrigeration systems. For handling the filters, this is important to wear gloves and a protective mask (FFP3), especially when dust is formed.

## ANNEX 2. SET OF QUESTIONS.

The check box () are used to have a quick view of the regulation. The text inbox host experience from the practical case study.

<b>ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY</b> <b>CASE STUDY 1</b>
<p><b>Could you please provide a short description of the case study and the workplace?</b> Case study 1 illustrate the situation of exceeding the radon reference level of 300 Bq/m<sup>3</sup>, which applies for the annual average radon gas concentration in "rooms where persons are regularly present for several hours per day" (art. 155 <a href="#">Radiation Protection ordinance (RPO)</a>). These could be e.g. rooms in dwellings, schools or ordinary workplaces in buildings. The competent authorities are the cantons (art. 158 RPO). In Case study 1, a company performed on own initiative passive radon measurements on ordinary workplaces in a building. The results indicated a concentration of 350 Bq/m<sup>3</sup> on annual average at a workstation located in the basement and occupied 2000 hours per year.</p>
<p><b># IDENTIFICATION OF WORKPLACES</b> Context: Radon measurements shall be carried out in identified workplaces</p>
<ul style="list-style-type: none"> <li>• <b>What are the criteria to select the workplaces?</b> <input type="checkbox"/> Workplace in basement <input type="checkbox"/> Workplace in ground floor <input type="checkbox"/> Map or radon-prone area <input type="checkbox"/> Specific workplace <input type="checkbox"/> former radon measurement <input checked="" type="checkbox"/> other: <i>own initiative</i></li> <li>• <b>Using the criteria:</b> <input type="checkbox"/> Mandatory <input checked="" type="checkbox"/> Not mandatory</li> <li>• <b>Performing radon measurement in the identified workplaces:</b> <input type="checkbox"/> Mandatory <input checked="" type="checkbox"/> Not mandatory</li> </ul>
<p><b>What are your views about the system for the identification of workplaces? What about all the other workplaces?</b> In buildings (except for schools and nursery schools, where the canton must ensure that approved radon measurements are carried out), the radon measurement is left to the individual responsibility of the owner (at its own cost). However, the canton may require the building owner to have radon measurements conducted (art. 164 RPO).</p>
<p><b># RADON CONCENTRATION MEASUREMENT</b> Context: Radon measurement protocol.</p>
<ul style="list-style-type: none"> <li>• <b>Normative protocol for radon concentration measurement</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Preference given to</b> <input checked="" type="checkbox"/> passive or <input type="checkbox"/> direct-reading measurement devices?</li> <li>• <b>Accredited/certified services for radon concentration measurements</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Are provisions for verification measurement provided in law?</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</li> </ul>
<p><b>What are your views about the protocol for radon concentration measurement?</b> According to RPO, radon measurements must be conducted by an approved radon measurement provider. The Federal Office of public health (FOPH) shall approve a radon measurement provider for a maximum period of five years if it has the specialist staff and measurement system required for due fulfilment of its responsibilities and can assure proper fulfilment of its responsibilities, and in particular if no conflicts of interest exist (art. 159 RPO). The requirements for approval as a radon measurement provider are available in French, German and Italian on the FOPH-Website: <a href="#">Link</a>. The FOPH publish a list of the approved radon measurement providers: <a href="#">Link</a>. Approved radon measurement providers are required to comply with the prescribed measurement protocols and to enter their data in the radon database within two months after the completion of measurements (art. 160 RPO). The prescribed measurement protocols are available in French, German and Italian on the FOPH-Website for <a href="#">dwellings</a>, <a href="#">schools/nursery schools</a>, <a href="#">workplaces</a> and <a href="#">radon-</a></p>

[exposed workplaces](#). The approved radon measurement providers set the prices of the measurements themselves. According to the measurement protocol for schools/nursery, the measurement provider shall inform the canton if the reference level of 300 Bq/m<sup>3</sup> is exceeded.

**What if < reference level?** Any (mandatory) requirements to reduce exposure ALARA?  
No

### # DIAGNOSIS AND REMEDIATION

Context: If > reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?**  Employer  Property Owner
- **Are accredited/certified services for radon concentration measurements mandatory?**  Mandatory  Not mandatory
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  Yes  No  
The FOPH publishes a [list of radon consultants](#) working in Switzerland who have undergone training and continuing education in accordance with the requirements of the [Ordinance on education in the field of radiation protection](#).
- **Is it needed?**  Yes  No  
**Time frame for remediation actions?** Recommendations concerning the urgency of remedial measures are provided in the [Radon guidelines](#).
- **Time frame for remediation follow-up measurement?** According measurement protocols, the follow-up measurements have to be carried out directly after remediation work.
- **Same protocol as initial measurement?**  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**

According to art. 166 RPO, if the reference level of 300 Bq/m<sup>3</sup> is exceeded, the building owner shall take the necessary remedial measures. Recommendations concerning the urgency of remedial measures shall be provided by the FOPH and the cantons (see [Radon guidelines](#), in French). If the building owner fails to take action, the canton may order radon remediation. If it is determined that the reference level is exceeded at a school or nursery school, the canton shall order radon remediation within three years after the time of determination. The costs of remediation shall be borne by the building owner.

### # GOING FURTHER

Context: Remedial action were not sufficient.

>>>> not relevant, see [Forms case studies 2 and 3](#)

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes  No
- **Who can perform the exposure assessment**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes  No  
Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**

...

### # MOVING TO PLANNED EXPOSURE SITUATION

Context: Workplaces with [Rn] > Reference Level and exposure < 6 mSv



>>>> not relevant, see Forms case studies 2 and 3

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  
 Yes  No
- **Who is responsible of implementing the requirements?**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning)  Yes  No
  - Signage or warning system  Yes  No
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)?  Yes  No
  - Provision of information to workers affected by a requirement, development of appropriate radiation protection culture  Yes  No
  - Re-measurement/re-assessment  Yes  No
  - Other ...  Yes  No

**Any details you would like to report?**

...

Context: Workplaces with [Rn] > Reference Level and exposure > 6 mSv

- **Who is responsible for the implementation of licencing requirements for the workers?**   
*Employer*  *Property Owner*
- **Are there practical difficulties in?**
  - Individual radiological surveillance: Dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.)  Yes  No
  - Categorization of workers?  Yes  No
  - Recording and reporting of result (dose register) and access to the results?  Yes  No
  - Protection of outside workers?  Yes  No
  - How do employers access/obtain advice from a radiation protection expert and training and education in radon  Yes  No
  - Other : ...  Yes  No

**Any details you would like to report?**

...

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

...



**ANNEX 2. SET OF QUESTIONS.**

The check box (☐) are used to have a quick view of the regulation. The text inbox host experience from the practical case study.

ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY Case Study 2
<p><b>Could you please provide a short description of the case study and the workplace?</b>            In addition to the reference level of 300 Bq/m<sup>3</sup>, a <b>threshold value of 1000 Bq/m<sup>3</sup></b> applies for the annual average radon gas concentration at "radon-exposed workplaces" (in order to protect workers). Ordinary workplaces at which the threshold value is exceeded are considered to be radon-exposed (art. 156 <a href="#">Radiation Protection ordinance (RPO)</a>). Case study 2 illustrate this situation in a building with ordinary workplaces.</p>
<p><b># IDENTIFICATION OF WORKPLACES</b>            Context: Radon measurements shall be carried out in identified workplaces</p>
<ul style="list-style-type: none"> <li>• <b>What are the criteria to select the workplaces?</b>  <input type="checkbox"/> Workplace in basement <input type="checkbox"/> Workplace in ground floor <input type="checkbox"/> Map or radon-prone area <input type="checkbox"/> Specific workplace <input type="checkbox"/> former radon measurement <input checked="" type="checkbox"/> other: <i>own initiative</i></li> <li>• <b>Using the criteria:</b> <input type="checkbox"/> Mandatory <input checked="" type="checkbox"/> Not mandatory</li> </ul>
<p><b>What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?</b>            In ordinary buildings (except for schools and nursery schools, where the canton must ensure that approved radon measurements are carried out), the radon measurement is left to the individual responsibility of the owner (at its own cost). However, the canton may require the building owner to have radon measurements conducted (art. 164 RPO).</p>
<p><b># RADON CONCENTRATION MEASUREMENT</b>            Context: Radon measurement protocol.</p>
<ul style="list-style-type: none"> <li>• <b>Normative protocol for radon concentration measurement</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Preference given to</b> <input checked="" type="checkbox"/> passive or <input type="checkbox"/> direct-reading measurement devices?</li> <li>• <b>Accredited/certified services for radon concentration measurements</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Are provisions for verification measurement provided in law?</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</li> </ul>
<p><b>What are your views about the protocol for radon concentration measurement?</b>            The prescribed measurement protocols are available in French, German and Italian on the FOPH-Website for <a href="#">dwellings</a>, <a href="#">schools/nursery schools</a>, <a href="#">workplaces</a> and <a href="#">radon-exposed workplaces</a>. According to the measurement protocol for workplaces, the measurement provider shall inform the concerned supervisory authorities (e.g. Suva in industrial and commercial enterprises, according art. 158 RPO) if the threshold value of 1000 Bq/m<sup>3</sup> is exceeded.</p>
<p><b>What if &lt; threshold value of 1000 Bq/m<sup>3</sup>?</b> Any (mandatory) requirements to reduce exposure ALARA?            If the measured radon concentration is below the threshold value of 1000 Bq/m<sup>3</sup>, but the reference level of 300 Bq/m<sup>3</sup> is exceeded, the building owner shall take the necessary remedial measures (art. 166 RPO). Recommendations concerning the urgency of remedial measures shall be provided by the FOPH and the cantons (see <a href="#">Radon guidelines</a>, in French). If the building owner fails to take action, the canton may order radon remediation. If it is determined that the reference level is exceeded at a school or nursery school, the canton shall order radon remediation within three years after the time of determination. The costs of remediation shall be borne by the building owner.</p>
<p><b># DIAGNOSIS AND REMEDIATION</b>            Context: If &gt; <b>threshold value of 1000 Bq/m<sup>3</sup></b>, remedial action to reduce radon concentration shall be taken.</p>

- **Who is responsible?**  Employer  Property Owner
- **Are accredited/certified services for radon concentration measurements mandatory?**  Mandatory  Not mandatory
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  Yes  No  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*
- **Is it needed?**  Yes  No
- **Time frame for remediation actions?** *immediately*
- **Time frame for remediation follow-up measurement?** *Accordinging measurement protocols, the follow-up measurements have to be carried out directly after remediation work.*
- **Same protocol as initial measurement?**  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**

According to art. 167 RPO, the enterprise must determine the annual radon-related effective dose to exposed persons and review this at least every five years, if the threshold value of 1000 Bq/m<sup>3</sup> is exceeded. For this purpose, it calls on an approved measurement provider for a measurement according to the protocol for [radon-exposed workplaces](#). If the effective dose to a person at the workplace is above 10 mSv per calendar year, the enterprise shall take organisational or technical measures to reduce the dose as rapidly as possible.

Concerning the technical measures, the FOPH publishes a [list of radon consultants](#) working in Switzerland who have undergone training and continuing education in accordance with the requirements of the [Ordinance on education in the field of radiation protection](#).

If, in spite of measures being taken, the effective dose to a person at the workplace is above 10 mSv per calendar year, this person is considered to be occupationally exposed.

**# GOING FURTHER**

Context: Remedial action were not sufficient.

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes (*when the threshold value of 1000 Bq/m<sup>3</sup> is exceeded*)  No
- **Who can perform the exposure assessment**  Employer (*generally with an approved measurement provider*)  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes  No
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**

[Ordinance on dosimetry \(Link, art. 39 and annex 12\).](#)

**# CASE WHERE EFFECTIVE DOSE < 10 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  Yes  No
- **Who is responsible of implementing the requirements?**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning) .....  Yes  No
  - Signage or warning system .....  Yes  No



- Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)? .....	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
- Control of exposure of workers .....	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
- Provision to "promote the development of an appropriate radiation protection culture" by the workers .....	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
- Re-measurement/re-assessment .....	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
- Other: ...	

**Any details you would like to report?**

If the threshold value of 1000 Bq/m<sup>3</sup> is exceeded, but the effective dose to workers <10 mSv per calendar year, the **enterprise** must review the annual radon-related effective dose to exposed persons at least every five years (according to art. 167 RPO).

In ordinary buildings, the **building owner** shall take the necessary remedial measures in order to achieve a radon gas concentration below the reference level of 300 Bq/m<sup>3</sup> according to art. 166 RPO (see Case study 1).

**# CASE WHERE EFFECTIVE DOSE ≥ 10 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  Employer  Property Owner
- **Are there practical difficulties in?**
  - Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.) .....  Yes  No
  - Categorization of workers? .....  Yes  No
  - Recording and reporting of result (dose register) and access to the results? .....  Yes  No
  - Protection of outside workers? .....  Yes  No
  - How do employers access/obtain advice from a radiation protection expert and training and education in radon .....  Yes  No
  - Other: ...

**Any details you would like to report? -**

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)  
 Yes, for example dose calculation and documentation

\*\*\*



**ANNEX 2. SET OF QUESTIONS.**

The check box () are used to have a quick view of the regulation. The text inbox host experience from the practical case study.

ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY Case study 3
<p><b>Could you please provide a short description of the case study and the workplace?</b>            Suva, as the supervisory authority in the fields of trade and industry, measured nearly 200 water supply companies according to article 165 al. 2 of the <a href="#">Radiation Protection ordinance (RPO)</a>. The aim of this campaign was to obtain a first global overview of the workers exposure in such facilities, which are categorised as <b>radon-exposed workplaces</b> according to article 156 of the RPO.</p>
<p><b># IDENTIFICATION OF WORKPLACES</b>            Context: Radon measurements shall be carried out in identified workplaces</p>
<ul style="list-style-type: none"> <li>• <b>What are the criteria to select the workplaces?</b>  <input type="checkbox"/> Workplace in basement <input type="checkbox"/> Workplace in ground floor <input type="checkbox"/> Map or radon-prone area <input checked="" type="checkbox"/> Specific workplace (<i>radon-exposed workplaces</i>) <input type="checkbox"/> former radon measurement <input type="checkbox"/> other:</li> <li>• <b>Using the criteria:</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> </ul>
<p><b>What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?</b>            A threshold value of 1000 Bq/m<sup>3</sup> applies for the annual average radon gas concentration at "radon-exposed workplaces" (in order to protect workers). Workplaces at which the threshold value is certainly or presumably exceeded are considered to be radon-exposed (art. 156). These are, in particular, workplaces in underground structures, mines, caverns and water supply installations, as well as those classified as radon-exposed by the supervisory authority. The supervisory authorities (e.g. Suva in industrial and commercial enterprises) are responsible for radon-exposed workplaces (art. 158 RPO). Enterprises with radon-exposed workplaces shall ensure that an approved measurement provider conduct radon measurements (art. 165 RPO). The costs of approved radon measurements at radon-exposed workplaces are borne by the enterprises.</p>
<p><b># RADON CONCENTRATION MEASUREMENT</b>            Context: Radon measurement protocol.</p>
<ul style="list-style-type: none"> <li>• <b>Normative protocol for radon concentration measurement</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Preference given to</b> <input checked="" type="checkbox"/> passive or <input type="checkbox"/> direct-reading measurement devices?</li> <li>• <b>Accredited/certified services for radon concentration measurements</b> <input checked="" type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> <li>• <b>Are provisions for verification measurement provided in law?</b> <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No</li> </ul>
<p>What are your views about the protocol for radon concentration measurement?            The prescribed measurement protocol for <a href="#">radon-exposed workplaces</a> is available in French, German and Italian.</p>
<p><b>What if &lt; threshold value of 1000 Bq/m<sup>3</sup>? Any (mandatory) requirements to reduce exposure ALARA?</b>            Not relevant for radon-exposed workplaces</p>
<p><b># DIAGNOSIS AND REMEDIATION</b>            Context: If &gt; threshold value of of 1000 Bq/m<sup>3</sup>, remedial action to reduce radon concentration shall be taken.</p>
<ul style="list-style-type: none"> <li>• <b>Who is responsible?</b> <input checked="" type="checkbox"/> Employer <input type="checkbox"/> Property Owner</li> <li>• <b>Are accredited/certified services for radon concentration measurements mandatory?</b> <input checked="" type="checkbox"/></li> </ul>

Mandatory  Not mandatory

- Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?  Yes  No
- Is it needed?  Yes  No

Time frame for remediation actions? **immediately**

- Time frame for remediation follow-up measurement? **According measurement protocols, the follow-up measurements have to be carried out directly after remediation work.**
- Same protocol as initial measurement?  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**

According to art. 167 RPO, the enterprise must determine the annual radon-related effective dose to exposed persons and review this at least every five years, if the threshold value of 1000 Bq/m<sup>3</sup> is exceeded. For this purpose, it calls on an approved measurement provider for a measurement according to the protocol for [radon-exposed workplaces](#). If the effective dose to a person at the workplace is above 10 mSv per calendar year, the enterprise shall take organisational or technical measures to reduce the dose as rapidly as possible.

Concerning the technical measures, the FOPH publishes a [list of radon consultants](#) working in Switzerland who have undergone training and continuing education in accordance with the requirements of the [Ordinance on education in the field of radiation protection](#).

If, in spite of measures being taken, the effective dose to a person at the workplace is above 10 mSv per calendar year, this person is considered to be occupationally exposed.

**# GOING FURTHER**

Context: Remedial action were not sufficient.

- Is it clear how to notify the situation to the competent authority?  Yes  No
- Is then the exposure assessment always requested?  Yes (*when the threshold value of 1000 Bq/m<sup>3</sup> is exceeded*)  No
- Who can perform the exposure assessment  Employer (*generally with an approved measurement provider*)  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?  Yes  No
- Is it needed?  Yes  No

**What are your views about the exposure assessment process?**

[Ordinance on dosimetry \(Link, art. 39 and annex 12\).](#)

**# CASE WHERE EFFECTIVE DOSE < 10 mSv**

- Is it clear how to notify the results of the exposure assessment to the competent authority?  Yes  No
- Who is responsible of implementing the requirements?  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- Are there practical difficulties in?
  - The identification of radon prone area (zoning) .....  Yes  No
  - Signage or warning system .....  Yes  No
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)? .....  Yes  No
  - Control of exposure of workers .....  Yes  No
  - Provision to "promote the development of an appropriate radiation protection culture" by the workers .....  Yes  No
  - Re-measurement/re-assessment .....  Yes  No

- Other: ...

**Any details you would like to report?**

If the threshold value of 1000 Bq/m<sup>3</sup> is exceeded, but the effective dose to workers <10 mSv per calendar year, the **enterprise** must review the annual radon-related effective dose to exposed persons at least every five years (according to art. 167 RPO).

In ordinary buildings, the **building owner** shall take the necessary remedial measures in order to achieve a radon gas concentration below the reference level of 300 Bq/m<sup>3</sup> according to art. 166 RPO (see Case study 1).

**# CASE WHERE EFFECTIVE DOSE  $\geq$  10 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  *Employer*  *Property Owner*

- **Are there practical difficulties in?**

- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.) .....  Yes  No
- Categorization of workers? .....  Yes  No
- Recording and reporting of result (dose register) and access to the results? .....  Yes  No
- Protection of outside workers? .....  Yes  No
- How do employers access/obtain advice from a radiation protection expert and training and education in radon .....  Yes  No

- Other: ...

**Any details you would like to report? -**

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

Yes, for example dose calculation and documentation

France.





**Questionnaire: from FRANCE**

The answers have been provided by M. Laurent from CARSAT Centre Ouest during an interview 6 July. The CARSAT is a social security organism and the only insurance provider against professional risks in France. It is therefore a key stakeholder for business/employers when it comes to risk prevention and health at work.

<b>ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY</b>
<p><b>Could you please provide a short description of the case study and the workplace?</b>  <i>The case study is composed of a combination of feedback from the management of radon in a factory of cooking equipment and in a veterinary clinic (the latter include underground premise), both located in the Limousin region.</i></p>
<p><b># IDENTIFICATION OF WORKPLACES</b></p> <p>Context: Radon measurements shall be carried out in identified workplaces</p>
<ul style="list-style-type: none"> <li>• <b>What are the criteria to select the workplaces?</b>  <i>x Workplace in basement x Workplace in ground floor x Map or radon-prone area x Specific workplace x former radon measurement <input type="checkbox"/> other: ...</i></li> <li>• <b>Using the criteria:</b> <input type="checkbox"/> Mandatory <input type="checkbox"/> Not mandatory</li> </ul> <p>N.B. All employers in all areas are required to undergo a documentary risk analysis based chiefly on the radon map, former measurements and the current construction and ventilation to decide and decide based on the result if the workplace should undergo a radon measurement or not.</p>
<p><b>What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?</b></p> <p>* Only a few companies are today aware of the radon regulation (the decrees have been published in 2018). In the Centre-Ouest: 10 companies have contacted the CARSAT. Only companies performing regulation overwatch or already dealing with IR are aware of the radon regulation and it will probably take years before the regulation become more known.</p> <p>* In practice, employers only use the radon map to decide to perform a radon measurement or not. Former measurement (in public places or other workplaces) are not available, consideration on building/ventilation are technical questions.</p> <p>* In public places (school, etc.), several regulations are now in application: one coming from the Health Code (public areas) and the one from Labour Code (the new one, dedicated to employees) and these may overlap, leading to questions from employers and workers.</p>
<p><b># RADON CONCENTRATION MEASUREMENT</b></p> <p>Context: Radon measurement protocol.</p>
<ul style="list-style-type: none"> <li>• <b>Normative protocol for radon concentration measurement</b> <input type="checkbox"/> Mandatory x <i>Not mandatory</i></li> <li>• <b>Preference given to</b> x <i>passive</i> or <input type="checkbox"/> <i>direct-reading measurement devices?</i></li> <li>• <b>Accredited/certified services for radon concentration measurements</b> <input type="checkbox"/> Mandatory x <i>Not mandatory</i></li> <li>• <b>Are provisions for verification measurement provided in law?</b> x <i>Yes</i> <input type="checkbox"/> <i>No</i></li> </ul> <p>N.B. Employers can auto-test the workplace. They can of course also contract a certified company to do so (not mandatory).</p>

**What are your views about the protocol for radon concentration measurement?**

\* Auto-test is cheap, which is advantageous for companies with many workplaces. This was the methods followed in the 2 case studies. Contracting a certified company require a much higher budget.

\* Nonetheless, error are fairly possible within an auto-testing scheme (ex. long storage of the dosimeters in inappropriate place). Plus, the employers will have a lot of practical questions: "where should I put the dosimeters? What about the places with limited presence of workers etc.". Indeed, the regulation does not introduce a time limit, ex. in hour/day, to decide if a place is relevant for radon measurement.

\* The Labour Directorate has teamed with experts to elaborate a practical guidebook to help employers in the implementation of the new regulation. A protocol for measurements is suggested and early feedback showed it is applied. However, this protocol differs from the normative NF protocol which shall be applied in the public places under the Public Health code.

\* CARSAT has already collaborate with employers in radon measurements campaign and has developed a methodology on its own. The methodology includes a pre-visit (including rough estimate of the number of dosimeters), a listing a dosimeters providers and an information briefing on radon for the workers. The presence at the briefing of the managers, workers representatives, medicine staff and health and safety officer (where there is one) are considered necessary. Another briefing to explain the results is also possible.

**What if < reference level? Any (mandatory) requirements to reduce exposure ALARA?**

There is no regulatory requirement below 300 Bq/m<sup>3</sup> and it is difficult to promote remediation action to the employers in this case.

The 300 Bq/m<sup>3</sup> is regarded as a limit or even a Limit Value for Professional Exposure (VLEP, a familiar concept for companies in France, ex. used for asbestos, chemical etc.) and not as a Reference Level under radiation protection definition.

**# DIAGNOSIS AND REMEDIATION**

Context: If > reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?** x *Employer*  *Property Owner*
- **Are accredited/certified services for radon concentration measurements mandatory?**  *Mandatory* x *Not mandatory*
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?** x *Yes*  *No*
- **Is it needed?** x *Yes*  *No*
- **Time frame for remediation actions?** If > 300 Bq/m<sup>3</sup>, "remediation could be done rapidly", if > 1 000 Bq/m<sup>3</sup>, "within a year". But this is not mandatory.
- **Time frame for remediation follow-up measurement?** After the remediation work.
- **Same protocol as initial measurement?** x *Yes*  *No* Integrated measurement is necessary but in option a continuous monitoring can be performed before the winter.

The regulation only advocates for "improvement of the sealing and the ventilation". This is very theoretical for employers. Only a few companies in France have expertise on diagnosis and remediation and for the moment, the questions from employers about what to do if above the RL are mainly addressed to the laboratory measurements, who eventually forward them to CARSAT. The Labour Directorate has issues additional recommendations for remediation in its

guidebook.

In the case study, the first attempt to decrease the radon concentration was not sufficient (2000 to 800 Bq/m<sup>3</sup>). A system of ventilation (positive pressure in the workplace) seems to have been a successful solution.

**Is the optimization principle considered in the implementation of the remedial action?**

Cost-efficacy consideration, numerical target, involvement of workers, ...

\* Some remediation companies only bring one-pill-solution without taking into consideration the building and the circumstances. In addition, it has been reported that these companies delegate the job to local workforce, and do not even take the time to visit the place. This is not ALARA compliant.

\* Most employers should be able to allocate a budget for the remediation (especially if there is a regulatory pressure). Nonetheless, the CARSAT has designed a financial aid to support small companies in the remediation, including the purchase of a radon continuous monitoring system.

\* Overall, the management of radon at the workplace follow a step-by-step approach and is chiefly developed today by radiation protection staff: RPE, RPO. Nonetheless, the question about the optimization of the protection against radon at the workplace remains open.

\* The CARSAT has engaged a process in building internal competences on radon (seminar, visit of laboratories, device handling etc.) and developing a national network of Radon Referent that will act in support of the employers.

\* Key advices include the development of radon competence in measurement and remediation, collaboration with existing networks and partners (building professionals) who has already experience in the field, collecting and sharing knowledge of achievements.

**# GOING FURTHER**

Context: Remedial action were not sufficient.

- **Is it clear how to notify the situation to the competent authority?** x *Yes*  *No* *by email*
- **Is then the exposure assessment always requested?** x *Yes*  *No*
- **Who can perform the exposure assessment** x *Employer*  *Property Owner* x *In-house Radiation Protection Expert* x *External Radiation Protection Expert*
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?** x *Yes*  *No* .
- **Is it needed?** x *Yes*  *No*

**What are your views about the exposure assessment process?**

Up to now, the CARSAT has no experience of any companies that went so far in the process. The formula to calculate the exposure (mSv) might raise questions, especially about the dose coefficients (the ICRP65 coefficient are used but the regulation is bound to change).

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  *Yes*  *No*
- **Who is responsible of implementing the requirements?**  *Employer*  *Property Owner*  *In-house Radiation Protection Expert*  *External Radiation Protection Expert*
- **Are there practical difficulties in?**

- The identification of radon prone area (zoning) .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Signage or warning system .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)? .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Control of exposure of workers .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Provision to "promote the development of an appropriate radiation protection culture" by the workers .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Re-measurement/re-assessment .....	<input type="checkbox"/> Yes <input type="checkbox"/> No
- Other: ...	
<b>Any details you would like to report?</b>	
...	
<b># CASE WHERE EFFECTIVE DOSE <math>\geq</math> 6 mSv</b>	
<ul style="list-style-type: none"> <li>• <b>Who is responsible for the implementation of licencing requirements for the workers?</b> <input type="checkbox"/> <i>Employer</i> <input type="checkbox"/> <i>Property Owner</i></li> <li>• <b>Are there practical difficulties in?</b> <ul style="list-style-type: none"> <li>- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.) .....</li> <li>- Categorization of workers? .....</li> <li>- Recording and reporting of result (dose register) and access to the results? .....</li> <li>- Protection of outside workers? .....</li> <li>- How do employers access/obtain advice from a radiation protection expert and training and education in radon .....</li> <li>- Other: ...</li> </ul> </li> </ul>	
<b>Any details you would like to report?</b>	
...	
<b>Are there practical difficulties for workplaces combining radon + other exposure from planned situation? (radiological surveillance, dose limit, ...)</b>	
...	

Ireland.

## **RADON IN WORKPLACES**

### **Regulations pertaining to Radon in the workplace**

In Ireland the following regulations apply to radon in the workplace

#### ***The Radiological Protection Act 1991 Ionising Radiation Regulations 2019 (SI 30 of 2019)***

These regulation transpose the BSS into Irish law. The scope of this legislation covers radiation protection of workers and members the public. This competent authority for enforcing this legislation is the Environmental Protection Agency (EPA).

The regulations set out the requirement for the establishment and Maintenance of a [National Radon Control Strategy](#). Phase 2 covers the period 2019 – 2014 and includes radon in the workplace.

The regulations governing radon in the workplace are as follows:

- The national reference level for indoor radon concentrations in workplaces is 300 Bq/m<sup>3</sup> .
- An employer or self-employed person who is responsible for a workplace shall measure the indoor radon concentrations where the workplace is:
  - underground, including mines and show caves;
  - on the ground floor or basement level in High Radon Areas (any 10km national grid square where it is predicted that greater than 10% of dwellings will have an annual average radon concentration above 200 Bq/m<sup>3</sup>).
  - Identified by the EPA as being liable to have radon concentrations above 300 Bq/m<sup>3</sup>
- Workplace measurements shall be carried out in accordance with guidelines issued by the EPA.
- If the result of any workplace radon measurement exceeds 300 Bq/m<sup>3</sup> , the employer or self-employed person, shall reduce the radon concentrations to below the national reference level. This work shall start as soon as practicable and be completed within 12 months of the date of radon measurement report.
- Following this, further radon measurements shall be carried out within one month of completion of the remedial measures, to determine whether the radon concentrations have been reduced to below 300 Bq/m<sup>3</sup> .
- Where the radon concentration continues to exceed 300 Bq/m<sup>3</sup> following remediation, the employer or self-employed person shall notify the EPA and assess the risk to workers according to EPA guidelines within three months of the notification
- Where following the assessment carried out above the workers are liable to receive an exposure in excess of 6 mSv per year, the employer shall apply the relevant requirements of the SI 30 of 2019.

#### ***Safety Health and Welfare Act 2005***

The Safety, Health and Welfare at Work Act 2005, which repealed and replaced the Safety, Health and Welfare at Work Act 1989 was brought in to make further provision for the safety, health and welfare of persons at work. This Act clarifies and enhances the responsibilities of employer's, the self-employed, employees and various other parties in relation to safety and health at work. The competent authority for enacting this legislation is the Irish Health and Safety Authority

Under the Safety, Health and Welfare at Work Act 2005, every employer has a general duty to identify hazards in the workplace to minimise them. In line with Article 66 of S.I. 30 of 2019 all workplaces at ground floor or basement level in High Radon Areas must be tested for radon.

Because it is impossible to predict exactly where high radon levels will be found, it is recommended that every workplace should have a radon test carried out, even those located outside high radon areas.

Outdoor workplaces such as agriculture, transport, construction and fishing are unaffected by high levels of radon, and do not need to be tested.

### ***Technical Guidance C of the Building Regulations***

If a workplace was built after 1st July 1998, the Technical Guidance Document C of the building regulations require that it is fitted with a standby radon sump. This is simple pipe work that extends from under the foundations into the outdoor air. If high radon levels are measured, the standby sump can be activated by adding a fan. It should be noted that a standby sump that has not been activated by adding a fan does not reduce radon levels.

### **Measurement protocols**

The EPA has developed [guidance for measuring radon in workplaces](#). The radon gas concentration shall be measured using a detector capable of integrating the radon exposure continuously over a period of not less than 3 months. Suitable devices include, but are not limited to CR-393 alpha track diffusion radon gas detectors. These measurements must be carried out by a measurement service registered with the EPA.

The following considerations should be noted when measuring radon in workplaces

- (a) The main entry route for radon into buildings is through cracks and gaps in the floor. Consequently, basement and ground floor rooms are likely to have the highest radon concentrations. Normally, therefore, a workplace survey should be made in workspaces located on the ground floor and in basement levels, where these are occupied.
- (b) It is not necessary to carry out measurements in areas such as corridors, washrooms, toilets, etc. which are unoccupied or occupied infrequently. As a general rule, an infrequently occupied area is one where an individual is unlikely to spend more than 100 hours per year of their working time.
- (c) The recommended number of detectors per workplace is based on the number of offices or on the floor area to be surveyed and on the workplace type. Recommended measurement densities are set out in Table 1 for different workplace types.

**Table 1. Survey Strategies for Above Ground Workplaces**

<b>Workplace type</b>	<b>Number of detectors</b>	<b>Examples</b>
Office type accommodation	One detector per individual office	Banks, schools, government premises, professional practices
Open plan office, and retail or workshop up to 1000 m <sup>2</sup> , also public access areas	One per 200m <sup>2</sup>	Administrative and call centres, light industry, hotel foyers
Areas from 1,000 to 5,000 m <sup>2</sup>	One per 400m <sup>2</sup>	Warehouses, small supermarkets
Very large areas of several thousand m <sup>2</sup>	One for each distinct area with obviously different environmental conditions. Not less than 1 per 500 m <sup>2</sup>	Large manufacturing or process plants, large warehouses
Basements	One in each separate room, section or area irrespective of size, even if infrequently used (but greater than 100 hours/year occupancy).	Bank vaults, mechanical and/or electrical control centres

There are currently [5 radon measurement](#) companies registered with the EPA. These companies have met the [relevant criteria](#) to become a radon testing service.

### **Reducing Radon in the workplace**

The EPA has produced [guidance for the remediation of above ground buildings](#) with elevated radon concentrations.

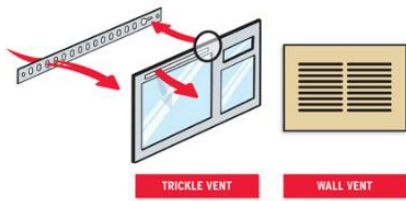
#### ***Radon Prevention***

If a workplace was built after 1st July 1998, the Technical Guidance Document C of the building regulations require that it is fitted with a standby radon sump. This is simple pipe work that extends from under the foundations into the outdoor air. If high radon levels are measured, the standby sump can be activated by adding a fan. It should be noted that a standby sump that has not been activated by adding a fan does not reduce radon levels.

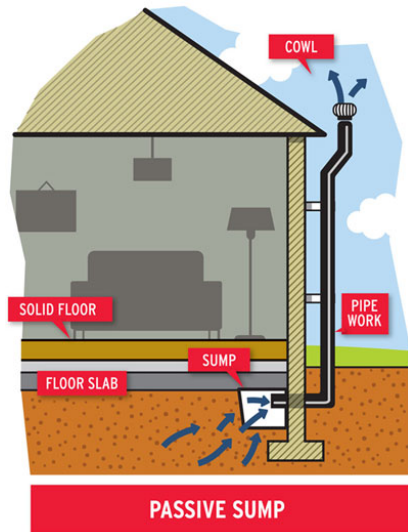
#### ***Reducing radon in existing buildings***

One of the simplest ways to dilute moderate levels of radon is to increase the indoor ventilation by installing wall vents or window trickle vents. This can reduce radon levels in your home by up to 50%. It is important that increased ventilation is installed at ground level only as additional ventilation on upper floors may increase the flow of radon from the ground into your home. This work usually costs in the region of a few hundred euro.

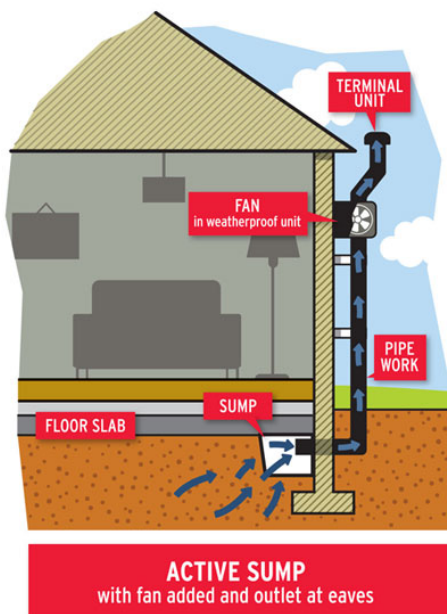




For radon levels up to  $400 \text{ Bq/m}^3$ , a passive sump can reduce radon levels by up to 50%. A passive sump is a sump system that works without the action of a fan. Instead, wind action over the top of the sump-pipe draws radon up through the sump system.



The most effective and most commonly used way of reducing radon in the workplace is by installing an active radon sump. A radon sump is a cavity about the size of a bucket immediately under the floor slab that is linked by pipe work to the outside. The radon rich air coming from the ground is drawn out from under the floor slab by a small electric fan in the pipeline and vented to outside before it is drawn into your home.



The EPA holds a list of registered radon remedial companies. There are currently 9 companies listed. A two day training course on radon remediation measures is available. This course is a prerequisite to being listed as a [registered radon remediation company](#) on the EPA's website.

## Other Initiatives

The EPA has developed a dedicated website for radon in Ireland [www.radon.ie](http://www.radon.ie). This is a valuable resource for employers looking for information on radon in the workplace. The includes an interactive radon predictive map where the employer can quickly determine whether their workplace is in a High Radon Area. General information on how to carry out a radon survey, a list of approved radon measurement companies, the steps to take when radon values are above the reference level and information on radon remediation techniques and a list of remediation companies is also available. Details guidance documents on all these areas are also available to download.

The EPA also provides a free radon advice service where the employer can avail of radon expertise acquired over many years BY EPA staff.

The EPA has developed a comprehensive [National Radon Control Strategy](#) which prominently features radon in the workplace. Some key outputs from the National Radon Control Strategy include:

- The establishment of a dedicated website for radon in Ireland ([www.radon.ie](http://www.radon.ie))
- The establishment of a registration scheme for radon measurement companies and radon remedial companies
- The establishment of training courses for radon remediation staff and construction personnel involved in the provision of membrane and sumps in new builds.

In 2019 the EPA held it 15<sup>th</sup> [national radon forum](#). This meeting provides the opportunity for experts in radon to meet on an annual basis to discuss and highlight radon issues. The forum usually has a section dedicated to radon in the workplace. This is an open forum and is free to attend by members of the public and employers.

## Case Study 1

### Radon in Schools

A comprehensive survey of radon in schools was carried out by the Radiological Protection Institute of Ireland on behalf of the Irish Department of Education. The objective of the survey was to assess the distribution of radon in Irish schools and to identify those requiring remedial work to reduce radon exposure to children and staff.

ALL of the 4000 state schools were invited to participate. Indoor radon concentrations were measured using passive alpha track-etch detectors with a measurement period of one academic year from September to the following June. Measurements were carried out in all ground floor classrooms and offices of 3444 schools, representing over 85% of the schools invited to participate. 898 schools had radon concentrations greater than 200 Bq/m<sup>3</sup> of which 241 had radon concentrations in excess of 400 Bq/m<sup>3</sup> with 66 having radon concentrations in excess of 1000 Bq/m<sup>3</sup> one or more ground floor classrooms.

In schools with radon concentrations below 400 Bq/m<sup>3</sup>, passive remediation through increased background ventilation (mainly wall vents and trickle vents in windows), was used to reduce the radon concentrations. Where the initial radon concentration exceeded 400 Bq/m<sup>3</sup>, an expert in radon remediation assessed the school and remedial measures specific to each school have been designed. In the majority of these cases fan assisted radon sumps were used to reduce radon levels.

The effectiveness of remedial measures was assessed and increased ventilation was found to reduce radon concentrations by an average of 47% while fan assisted sumps resulted in average reductions in radon concentrations of 82%. Only 6% of the remediated schools had radon concentrations above 400 Bq/m<sup>3</sup> and required further work to reduce levels further.

Norway.



## **EAN Working Group on the Application of ALARA for Radon At Work (A-RAW)**

### **Why a Survey on radon?**

National regulations for the protection against radon at the workplace have recently evolved in Europe. In general, the number of workplaces affected by the regulations has increased; including many workplaces not previously aware of the radiation protection system. Furthermore, the practical application of the regulation for radon, using a step-by-step approaches, with reference level/exposure values, might be challenging in practice. It can raise questions from employers and other affected parties and communication might be an issue

As a consequence, the European ALARA Network has set up, in 2021, a working group to investigate the practical implementation of the ALARA principle in relation to exposure from Radon At the Workplace (A-RAW).

### **The objective**

The objective of the working group is to collate a sample of practical experiences in Europe (1~2 case studies per country), detailing the controls and measures implemented to protect against radon exposure in the workplace.

A set of questions to assist the description of suitable case studies is proposed (cf. below). It focuses on the steps taken to identify and manage workplaces with regard to radon.

The Working Group aims to synthesize the experiences collected from the field

1. Commonalities and differences
2. Lessons-learned,
3. good practices and difficulties in application.

These information can be useful to discuss the application of ALARA principle in these situations, address potential gaps and identify if actions (ex. guidance) are needed in the future and by who. The Working Group aims to share these results to the concerned radiation protection community and will work on identifying opportunities to do so.



## SET OF QUESTIONS.

**1 survey = 1 case study of your choice** (workplace concerned with regulation on radon: touristic cave, underground workplace, bakery, robot factory ...)

The check box (; ) are used to have a quick view of the national regulation. The text inbox host experience from the practical case study.

### ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY

**Could you please provide a short description of the case study and the workplace?**

*Context, sitting, number of workers etc.*

Instead of an actual case study, DSA would like to give a short overview of radon regulation in workplaces in Norway. The EU BSS Directive is not implemented in the national legislation, owing to the fact that Norway is not a member of the EU and thus not bound by the directive. However, it is a goal to be in line with the rest of Europe on the matter of radon and radiation protection, and in most areas we fulfil the requirements on radon.

In Norway, radon in the workplaces is regulated in general terms in the Working Environment Act and in the occupational Safety and Health regulation. The employer shall ensure a fully satisfactory working environment, and the employer shall also ensure that all radiation exposure is kept at the lowest possible level. The Norwegian Labour Inspection Authority is the responsible authority.

Generally, there are no legally binding limit values or occupational exposure limits or a specific reference level for radon in the workplace. However, the DSA general recommendations on radon levels (100 Bq/m<sup>3</sup> and 200 Bq/m<sup>3</sup> as action and maximum level, respectively) should be taken into account when considering radon exposure in the working environment. This advice is given in guidelines from the Norwegian Labour Inspection Authority. Radon levels in schools and kindergartens, however, are regulated with legally binding indoor limits (100 Bq/m<sup>3</sup> and 200 Bq/m<sup>3</sup> as action and maximum level, respectively) as a part of the Regulations on Radiation Protection.

Generally, measurements are not mandatory for the workplace, neither in defined radon areas or for specific types of workplaces. However, the employer is responsible and has to consider, and is advised by the Norwegian Labour Inspection Authority and DSA, to do measurements. This applies to all kind of workplaces, all over the country. An exception is again radon levels in schools and kindergartens. Here radon measurements are mandatory and should be done according to a specific measurement protocol for radon in schools and kindergartens (more information in the text below).

For underground workplaces, which are especially exposed for high radon concentrations, the Norwegian Labour Inspection Authority has provided specific guidance.

### # IDENTIFICATION OF WORKPLACES

Context: Radon measurements shall be carried out in identified workplaces

- **What are the criteria to select the workplaces?**

Workplace in basement  Workplace in ground floor  Map or radon-prone area  Specific workplace  former radon measurement  other: ...

- **Using the criteria:**  Mandatory  Not mandatory

**What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?**

### # RADON CONCENTRATION MEASUREMENT

Context: Radon measurement protocol.

- **Normative protocol for radon concentration measurement**  Mandatory  Not mandatory

- **Preference given to**  passive or  direct-reading measurement devices?

- **Accredited/certified services for radon concentration measurements**  Mandatory  Not mandatory

- **Are provisions for verification measurement provided in law?**  Yes  No

**What are your views about the protocol for radon concentration measurement?**

Issues in practicality, cost, information to the workers and/or Health and Safety

DSA has published a measurement protocol for schools and kindergartens. According to Regulations on Radiation Protection 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 and Nuclear Safety Authority (DSA)". Measurements carried out according to this protocol, will qualify as a documentation of radon levels present in kindergartens and schools.

The protocol can also act as a guide for other large buildings. (See:

[https://dsa.no/en/publications/\\_/attachment/inline/0e6876ed-c155-4c82-998a-adb8fb1956ea:59e6ddec67056552873529caa7dd89d09f0c0ef/Protocol%20for%20radon%20measurements%20in%20schools%20and%20kindergartens.pdf](https://dsa.no/en/publications/_/attachment/inline/0e6876ed-c155-4c82-998a-adb8fb1956ea:59e6ddec67056552873529caa7dd89d09f0c0ef/Protocol%20for%20radon%20measurements%20in%20schools%20and%20kindergartens.pdf))

Radon measurements are mandatory for all schools and kindergartens in Norway. No area in the country is excepted.

The measurement protocol has a two-tiered approach:

- First step: long-lasting measurements, minimum two months during winter season, that should eventually indicate elevated radon levels in the air.
  - If  $< 100 \text{ Bq/m}^3 \rightarrow \text{OK}$
  - If  $> 100 \text{ Bq/m}^3 \rightarrow \text{second step}$
- Second step: shorter time measurements that can indicate the possible effects of air ventilation and value on radon concentrations in the air in working period/active period during the day.
  - If  $< 100 \text{ Bq/m}^3 \rightarrow \text{OK}$

- If  $> 100 \text{ Bq/m}^3 \rightarrow$  measures to reduce radon are needed

If measures to reduce radon are implemented, new radon measurements are required. If the radon levels, after the implementation of radon-reducing measures, still exceed the action limit ( $100 \text{ Bq/m}^3$ ), but are below the maximum limit ( $200 \text{ Bq/m}^3$ ), the requirements are met.

**What if  $<$  reference level?** Any (mandatory) requirements to reduce exposure ALARA?

According to the Regulations on Radiation Protection and Use of Radiation all "use of radiation shall be optimised. This implies that the ionising radiation exposure shall be as low as practically achievable, considering technological knowledge, social and economic factors." The DSA radon recommendations state that "action may also be appropriate below the action limit". (See also answer in next section.)

In addition, the Regulations concerning the Performance of Work state: "The employer shall ensure that all radiation exposure is kept at lowest possible level."

-

### # DIAGNOSIS AND REMEDIATION

Context: If  $>$  reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?**  Employer  Property Owner
- **Are accredited/certified services for radon concentration measurements mandatory?**  Mandatory  Not mandatory
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  Yes  No  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*
- **Is it needed?**  Yes  No
- **Time frame for remediation actions?** A specific time frame is not given, but it should be done as quickly as reasonably possible, and normally within a year.
- **Time frame for remediation follow-up measurement?** A specific time frame is not given, but it should be done as quickly as reasonably possible, and normally within a year.
- **Same protocol as initial measurement?**  Yes  No

**Is the optimization principle considered in the implementation of the remedial action?**

Cost-efficacy consideration, numerical target, involvement of workers, ...

The optimization principle is to a certain extent included in the DSA general radon recommendations: In buildings with rooms of high occupancy where radon levels exceed  $100 \text{ Bq/m}^3$  (action limit) DSA recommends that effective radon measures should be initiated. If the final value following completion of the measures is still above  $100 \text{ Bq/m}^3$ , and below  $200 \text{ Bq/m}^3$  (maximum limit), but is considered to be as low as possible for the building concerned, the outcome may be considered to be satisfactory in the case in question. The level should always be below the maximum limit of  $200 \text{ Bq/m}^3$ , given as the annual mean radon concentration.



**# GOING FURTHER**  
Context: Remedial action were not sufficient.

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes  No
- **Who can perform the exposure assessment**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes  No  
*Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.*
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**

The employer is responsible for ensuring a fully satisfactory working environment, and also that all radiation exposure is kept at the lowest possible level. If the radon level doesn't meet the general recommendations, the employer is advised to assess the radon exposure to the workers.

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  Yes  No
- **Who is responsible of implementing the requirements?**  Employer  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning)  Yes  No  
.....
  - Signage or warning system  Yes  No  
.....
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)?  Yes  No  
.....
  - Control of exposure of workers  Yes  No  
.....
  - Provision to "promote the development of an appropriate radiation protection culture" by the workers  Yes  No  
.....
  - Re-measurement/re-assessment  Yes  No  
.....
  - Other: ...

**Any details you would like to report?**

If the radon level is above the general recommendations (100 Bq/m<sup>3</sup> and 200 Bq/m<sup>3</sup>), despite actions to lower the concentration, then the actual radon exposure to the workers should be calculated. If the actual exposure is above 0.36 MBq/m<sup>3</sup>, the employer should inform the

employees, and the workplace should be measured more regularly to ensure updated exposure calculations. Regular assessments should be made and procedures to ensure that the radon exposure to the workers is kept as low as reasonably achievable. For purpose-built workplaces, such as hydro-electric power stations and office-like workplaces, the guidance set an upper exposure limit at 0.72 MBqh/m<sup>3</sup> (corresponds approximately to an effective dose at 6 mSv).

**# CASE WHERE EFFECTIVE DOSE ≥ 6 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  Employer  Property Owner

- **Are there practical difficulties in?**

- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.)  Yes  No

- Categorization of workers?  Yes  No

- Recording and reporting of result (dose register) and access to the results?  Yes  No

- Protection of outside workers?  Yes  No

- How do employers access/obtain advice from a radiation protection expert and training and education in radon  Yes  No

- Other: ...

**Any details you would like to report?**

If the 0.72 MBq/m<sup>3</sup> limit can be exceeded for other underground workers, like miners and tunnel engineering workers, their individual exposure should be monitored or measured and calculated yearly, preferably with individual radon exposure measurements. In addition, the guidance recommends medical surveillance (e.g. a medical conversation with a doctor) and specific training, regular assessments and procedures to ensure that the radon exposure to the workers is kept as low as reasonably achievable. For underground workers like miners and tunnel engineering workers, 2.1 MBqh/m<sup>3</sup> is the upper recommended limit and should never be exceeded (corresponds approximately to an effective dose at 20 mSv).

**Are there practical difficulties for workplaces combining radon + other exposure from planned situation?** (radiological surveillance, dose limit, ...)

Yes, and better recommendations for workers/employers on this issue is needed.

Slovenia.



## **EAN Working Group on the Application of ALARA for Radon At Work (A-RAW)**

### **Why a Survey on radon?**

National regulations for the protection against radon at the workplace have recently evolved in Europe. In general, the number of workplaces affected by the regulations has increased; including many workplaces not previously aware of the radiation protection system. Furthermore, the practical application of the regulation for radon, using a step-by-step approaches, with reference level/exposure values, might be challenging in practice. It can raise questions from employers and other affected parties and communication might be an issue

As a consequence, the European ALARA Network has set up, in 2021, a working group to investigate the practical implementation of the ALARA principle in relation to exposure from Radon At the Workplace (A-RAW).

### **The objective**

The objective of the working group is to collate a sample of practical experiences in Europe (1~2 case studies per country), detailing the controls and measures implemented to protect against radon exposure in the workplace.

A set of questions to assist the description of suitable case studies is proposed (cf. below). It focuses on

the steps taken to identify and manage workplaces with regard to radon.

The Working Group aims to synthesize the experiences collected from the field

1. Commonalities and differences
2. Lessons-learned,
3. good practices and difficulties in application.

These information can be useful to discuss the application of ALARA principle in these situations, address potential gaps and identify if actions (ex. guidance) are needed in the future and by who. The Working Group aims to share these results to the concerned radiation protection community and will work on identifying opportunities to do so.



## SET OF QUESTIONS.

**1 survey = 1 case study of your choice** (workplace concerned with regulation on radon: touristic cave, underground workplace, bakery, robot factory ...)

The check box (; ) are used to have a quick view of the national regulation. The text inbox host experience from the practical case study.

### ALARA FOR RADON AT WORK TEMPLATE FOR CASE STUDY

**Could you please provide a short description of the case study and the workplace?**

Cave tourism is a very old activity in Slovenia. The first recorded tourist visit to a cave in Slovenia took place in Postojna Cave in 1213, as evidenced by the signature found in the Rover of Old Signatures. The year 1819 was a turning point for cave tourism as we know it today. After the discovery of the inner parts of the Postojna Cave in 1818, the cave was adapted for tourism and was inaugurated on 17 August 1819. After the opening of Postojna Cave for tourism in 1819, a suitable solution was sought for decades to ease the long and tiring journey through the cave in the torchlight. On 11 March 1857, at the opening of the Vienna-Trieste Southern Railway, three carriages were prepared for the visit of the imperial couple Franz Joseph and Elisabeth. The world's first railway in a stalactite cave was opened in the Postojna Cave on 16 June 1872. The cave guides pushed two carriages called Faeton that could carry four visitors each through the cave, followed by the introduction of petrol locomotives, which were gradually replaced by electric locomotives from 1956 to 1988. Postojna Cave is Slovenia's most globally recognised attraction, as confirmed by the fact that it has hosted visitors from more than 150 different countries. Postojna Cave has been keeping records of the number of visitors since 1819 and in September 2021 they welcomed the 40 millionth visitor (source: <https://www.postojnska-jama.eu/en/wonderland-stories/>).

Tourist workers employed at Postojna Cave receive the highest radiation doses from exposure to *radon and its progeny* in the Republic of Slovenia. In 2020, 48 workers received a collective dose of 152 man-mSv. Due to the Covid-19 epidemic and the closure of the tourism sector, the doses received by tourism workers in 2020 were significantly lower than in 2019 when 116 workers received a collective dose of 996 man-mSv, i.e., 8.6 mSv of average individual dose.

Individual doses are assessed from the radon concentration measurements in the cave and occupancy time for each worker. The findings of a study in 2005 on the exposure of individuals in Karst caves, show that the doses of tourist workers in Karst caves due to radon exposure, assessed according to the ICRP 65 model, are underestimated. Due to the high unattached fraction of radon progeny in the atmosphere of the Karst caves, the ICRP 32 model should be used and an approximately two-times higher dose factor should be taken into account. Therefore, the received doses from radon and its progeny are assessed according to the ICRP 32 model. The doses calculated in such a manner are thus twice as high as those calculated according to the ICRP 65 model.

Individual monitoring due to radon exposure for tourist guides in Postojna cave is mandatory since 1995. However, measurements of radon concentration and dose assessment for research or radiation protection purposes had been performed in Postojna cave for couple decades before 1995.

### # IDENTIFICATION OF WORKPLACES

Context: Radon measurements shall be carried out in identified workplaces

- **What are the criteria to select the workplaces?**
  - Workplace in basement  Workplace in ground floor  Map or radon-prone area ✓
  - Specific workplace**  former radon measurement  other: ...
- **Using the criteria:** ✓ **Mandatory**  Not mandatory

**What are your views about the system for the identification of workplaces? And what happens to all the other workplaces?**

Employers are obligated to conduct radon concentration measurements:

- in basement or ground floor workplaces in radon prone areas
- workplaces where higher radon concentrations are expected like spas or sources of radon from the water, caves, mines, or other underground workplaces.

In parallel, SRPA is conducting a systematic surveillance and measurement of radon, dose rates and other relevant quantities, ensures identification of exposure due to radon:

- in facilities intended for educational, training, cultural or health care programmes;
- in living quarters located on the basement or ground floor or other areas where annual average radon concentrations may be expected to exceed reference levels;
- external exposure indoors in existing buildings due to the construction materials used;
- radon exposures in situations where higher radon concentrations can be expected, such as in spas, caves, mines, and other underground locations.

If systematic radon surveillance or radon measurements at workplaces indicate that annual average radon concentrations exceed reference level (300 Bq/m<sup>3</sup>), exposures of workers or members of the public should be assessed.

If the exposure assessment indicates that people in public buildings or workers in workplaces may receive an annual effective dose greater than 6 mSv from exposure to radon, exposure measures to reduce radon such as ventilation of the premises, relocation of people to other premises, cessation of use of the premises and construction interventions should be implemented. Reconstruction of the building is applied if it is assessed that will contribute sufficiently to reducing exposure and comparable results cannot be achieved by other simpler measures. Reorganisation of work tasks and working hours may also be a measure to reduce workers' exposure.

If the exposure assessment shows that, despite exceeding the average reference levels for radon concentration, people in public buildings or workers in workplaces receive an annual effective dose of less than 6 mSv, the measures referred to in the preceding paragraph are not necessary, but the conditions affecting exposure must be monitored and doses reassessed in the event of changes. In practice although in such cases remediation measures are not mandatory, ALARA principle is applied, and exposure is optimised if possible.

If despite implementing the measures described above workers receive the annual effective dose due to radon exposure which is higher than 6 mSv, the employer must implement measures for radiation protection of exposed workers in planned exposure situations. Appropriate measures are ordered by regulatory authority (Slovenian Radiation Protection Administration).

In case of Postojna cave tourist guides are classified as radiation workers of category A. They are under health surveillance and undergo the training in radiation protection. Individual doses are assessed from the radon concentration measurements in the cave and occupancy time for each worker. Those arrangements are in place since 1995.

#### # RADON CONCENTRATION MEASUREMENT

Context: Radon measurement protocol.

- **Normative protocol for radon concentration measurement**  *Mandatory*  *Not mandatory*
- **Preference given to**  *passive* or  *direct-reading measurement devices?*
- **Accredited/certified services for radon concentration measurements**  *Mandatory*  *Not mandatory*
- **Are provisions for verification measurement provided in law?**  *Yes*  *No*

#### What are your views about the protocol for radon concentration measurement?

Issues in practicality, cost, information to the workers and/or Health and Safety

The government of RS adopted a national radon programme to manage long-term health risks from exposure to radon establishing:

- a strategy for the management of increased exposures due to radon, including objectives and performance indicators to reduce health risks. The strategy is taking into account the principle of optimisation of protective measures;
- reference levels of radon concentrations in the working and living environment;
- criteria for the designation of radon-prone areas and specific radiation protection measures in these areas;
- the method and methodology for the determination of annual average radon concentrations;
- the systematic surveillance programme;
- the method, type and extent of measurements:
  - in the framework of the systematic surveillance,
  - the carrying out of measurements at the workplaces and
  - the carrying out of repeat measurements to verify the measures taken
- the methodology for estimating doses due to exposure to radon;



- a programme to raise awareness among employers, the public and professionals of the health risks due to exposure to radon and of the additional risks associated with smoking and of the importance of radon measurements and measures to reduce exposure.

General framework of radon concentration measurements is described under # IDENTIFICATION OF WORKPLACES. Specific provisions regarding radon concentration measurements protocols are defined in national radon programme. Services performing the measurements need an accreditation according to ISO 17025.

**What if < reference level?** Any (mandatory) requirements to reduce exposure ALARA?

If the reference level is not exceeded, measures to reduce exposure are not necessary. If the exposure assessment shows that, despite exceeding the reference level, people in public buildings or workers in workplaces receive an annual effective dose of less than 6 mSv, the measures for reducing the exposure are not necessary, but the conditions affecting exposure must be monitored and doses reassessed in the event of changes. In practice although in such cases remediation measures are not mandatory, ALARA principle is applied, and exposure is optimised if possible.

#### # DIAGNOSIS AND REMEDIATION

Context: If > reference level, remedial action to reduce radon concentration shall be taken.

- **Who is responsible?**  **Employer**  *Property Owner*
- **Are accredited/certified services for radon concentration measurements mandatory?**  **Mandatory**  *Not mandatory*
- **Are guidance available to help establish a diagnosis of the building and inform the type of mitigation required?**  **Yes**  *No*  
*Ex. Guidance on best practices, definition of standards for corrective measures (technical, organizational, cost) and their long-term follow-up.*
- **Is it needed?**  **Yes**  *No*
- **Time frame for remediation actions?** Defined in the order issued by the regulatory authority for each individual building/workplace.
- **Time frame for remediation follow-up measurement?** **6 months after remediation and then every 7 years**
- **Same protocol as initial measurement?**  **Yes**  *No*

**Is the optimization principle considered in the implementation of the remedial action?**

Cost-efficacy consideration, numerical target, involvement of workers, ...

...

Yes, national radon programme defines that the measures should be commensurated with the exposure and economically efficient in order to obtain efficient and permanent reduction of exposure.

#### # GOING FURTHER

Context: Remedial action were not sufficient.



**Is the optimization principle considered in the implementation of the remedial action?**

Cost-efficacy consideration, numerical target, involvement of workers,

- **Is it clear how to notify the situation to the competent authority?**  Yes  No
- **Is then the exposure assessment always requested?**  Yes  No (only if reference level is exceeded)
- **Who can perform the exposure assessment**  Employer  Property Owner  In-house Radiation Protection Expert  **External Radiation Protection Expert**
- **Are data/guidance available for the determination of annual radon concentration and "theoretical" estimate of effective dose to workers?**  Yes (defined in the national radon programme)  No  
*Ex. calculation techniques for estimating the radon concentration average and effective dose: respiratory/breathing rate, time in contact with radon, which conversion factors do you use, equilibrium factor etc.*
- **Is it needed?**  Yes  No

**What are your views about the exposure assessment process?**

...

**# CASE WHERE EFFECTIVE DOSE < 6 mSv**

- **Is it clear how to notify the results of the exposure assessment to the competent authority?**  Yes  No
- **Who is responsible of implementing the requirements?**  **Employer**  Property Owner  In-house Radiation Protection Expert  External Radiation Protection Expert
- **Are there practical difficulties in?**
  - The identification of radon prone area (zoning) (defined in the national radon programme)  Yes  **No**
  - Signage or warning system  Yes  **No**
  - .....
  - Ventilation/airflow requirements? And checks on continued operation of radon countermeasures (fans/sumps)? **Thus control measurement every seven years were introduced**  Yes  No
  - Control of exposure of workers  Yes  **No**
  - .....
  - Provision to "promote the development of an appropriate radiation protection culture" by the workers  Yes  **No**
  - .....
  - Re-measurement/re-assessment  Yes  **No**
  - .....
  - Other: ...

**Any details you would like to report?**

...

**# CASE WHERE EFFECTIVE DOSE ≥ 6 mSv**

- **Who is responsible for the implementation of licencing requirements for the workers?**  **Employer**  Property Owner



<ul style="list-style-type: none"><li>• <b>Are there practical difficulties in?</b><ul style="list-style-type: none"><li>- Individual radiological surveillance: dosimetry system (calculation hypothesis, EAP, personal dosimeter (incl. market analysis) against ambient measurement, etc.) <b>Ambiguities related to "new" ICRP dose factors</b> <input checked="" type="checkbox"/> <b>Yes</b> <input type="checkbox"/> <b>No</b></li><li>- Categorization of workers? <input type="checkbox"/> <b>Yes</b> <input checked="" type="checkbox"/> <b>No</b></li><li>.....</li><li>- Recording and reporting of result (dose register) and access to the results? <input type="checkbox"/> <b>Yes</b> <input checked="" type="checkbox"/> <b>No</b></li><li>.....</li><li>- Protection of outside workers? <input type="checkbox"/> <b>Yes</b> <input checked="" type="checkbox"/> <b>No</b></li><li>.....</li><li>- How do employers access/obtain advice from a radiation protection expert and training and education in radon : <b>Measures for exposed workers in the planed exposure situation apply. Advice is obtained via radiation protection assessment and training in radiation protection is mandatory for all workers.</b> <input type="checkbox"/> <b>Yes</b> <input checked="" type="checkbox"/> <b>No</b></li><li>- Other: ...</li></ul></li></ul>
<b>Any details you would like to report?</b> ...
<b>Are there practical difficulties for workplaces combining radon + other exposure from planned situation?</b> (radiological surveillance, dose limit, ...) ...

\*\*\*

United Kingdom.

# Radon in workplaces

## Section 1 - overview of UK framework

### 1.1 Relevant regulations:

Health & Safety at Work Act 1974 (HSAWA74) – employers must ensure H&S of employees and others who have access to their work environment

Management of Health & Safety at Work Regulations 1999 (MHSWR) – require the assessment of health and safety risks

Ionising Radiations Regulations 2017 (IRR17) – apply where workplace exceeds reference level of 300 Bq/m<sup>3</sup> (annual average) and employer must take action to restrict exposures

Ionising Radiations (Basic Safety Standards) (Miscellaneous Provisions) Regulations 2018 (requirements: to set reference level for indoor radon exposures of public; national radon action plan; publish information on radon health risks, measurements and remediation; measures to prevent radon ingress in new buildings)

Provision and Use of Work Equipment Regulations 1998 (PUWER) – for maintenance of radon mitigation equipment/technology

Building Regulations - in certain areas: protective measures to prevent radon ingress

### 1.2 Guidance:

Practical remediation methods and supporting technical guidance to reduce radon concentrations available from various sources including UKRadon and Building Research Establishment (BRE).

### 1.3 Action levels

UK Radon Action level for **homes**: 200 Bq/m<sup>3</sup> (in place since 1990)

A supporting Target Level (100 Bq/m<sup>3</sup>) was introduced in 2010 as a target for remediation, and a level above which those at higher individual risk (smokers and ex-smokers) should seriously consider radon reduction.

UK Radon Action level for **workplaces**: 300 Bq/m<sup>3</sup>

### 1.4 Identification of workplaces (decision whether to measure radon level)

Radon Affected Areas are those where at least 1% of the homes are expected to exceed the UK radon action level (reference level for homes).

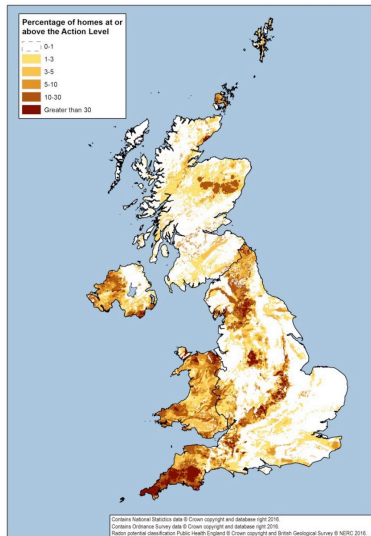
Measurements are mainly recommended for buildings located in a radon Affected Area (based on indicative radon maps - Figure 1)

And

For basement (below ground) rooms/workplaces that are regularly occupied, irrespective of their location.

Or, where there are other reasons to suspect a radon atmosphere, for example:

- the premises are located on un-remediated land contaminated with radium-226
- the premises include rooms that are used to store geological specimens containing uranium-rich minerals
- the site includes significant activities of radium-226, for example museums with a collection of radium-painted dials



#### Awareness of requirements promoted via:

Targeted campaigns to specific groups (i.e. schools, areas with radon potential >5% of properties) in partnership with local authorities

Identified as part of all property transactions (radon search is a required local authority 'search')

Ongoing provision of information and guidance

Workplace health & safety

Training of Environmental Health Officers

Training of Building Services Engineers (CPD)

Radon Awareness Week

Annual UK Radon Forum

Figure 1: indicative UK radon map

## 1.5 Radon concentration measurement

Most measurements are made with passive monitors that are left in place for three months. Protocols have been established to assist employers with determining the appropriate number of monitors for a given building (dependent on internal area/layout). Aim of measurement is to:

- confirm whether the reference level is exceeded
- identify which areas/rooms have the highest radon concentrations
- assist with the design of mitigation work
- inform the risk assessment

Active monitors are also available and may be used in some workplaces (e.g. mines) to supplement passive radon measurements.

Validation scheme in place for organisations offering radon measurement services for homes and workplaces.

Regular international intercomparison exercises are available to enable those offering radon measurement services to check the technical performance of their measurement capability.

Annual average result (Bq/m <sup>3</sup> )	Do the Ionising Radiations Regulations (IRR17) apply?
< 300	The IRR17 do not apply. No radon controls required. The employer should simply keep a record of the results and review them after around ten years (or more often for basements/mines) or if there are significant changes to the workplace structure or use.
> 300	IRR17 apply. Employers may be advised to undertake another set of measurements to determine if the estimated annual average value reported is accurate <sup>1</sup> . This may require monitoring over the course of a year. A radiation risk assessment should be carried out and action should be taken to reduce/manage radon exposure. Information should be given to employees about the nature and level of the risk. The employer must notify the competent authority (HSE) immediately that they are working in a radon atmosphere. This notification must be made, even if the employer is planning to remediate the workplace.

## 1.6 Diagnosis and remediation

First step for employers is usually to reduce the concentration of radon by increasing ventilation or drawing radon gas outside the building (using sumps/fan). Normally the work should be carried out within six months of receiving the initial measurement results.

Specific guidance for individual properties/workplaces, such as the design and location of remediation systems, is available from specialist companies in the radon sector, lists of services are given on the Radon Council and UK Radon Association websites. There is currently no accreditation scheme for companies providing radon remediation services.

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<sup>1</sup> There may be some variation in what monitoring an employer undertakes depending on what their qualified expert (RPA) advises.

Remedial methods (ref: <https://www.ukradon.org/information/reducelevels>)

Floor type	Solid		Suspended	
Radon level* (Bq m <sup>-3</sup> )	Under 500	Over 500	Under 500	Over 500
Recommended solutions, best first	Radon sump or Positive ventilation	Radon sump	Natural under-floor ventilation or Positive ventilation	Mechanical under-floor ventilation or Natural under-floor ventilation

For houses with mixed floor types, a combination of the above can be used.

\*The level of 500 Bq m<sup>-3</sup> is an approximate guide

Post mitigation radon measurements (for 2-3 months) are required to determine whether the work has been successful, with regular maintenance checks thereafter to show that it remains effective (i.e. checks that fans are still working).

If the radon levels have been reduced to comfortably below 300 Bq/m<sup>3</sup> the work is considered to have been successful; a radon level only marginally below the IRR17 threshold may not be 'ALARP' and improving the efficiency of the system should be recommended where feasible. Thereafter, an annual confirmatory midwinter measurement is appropriate. If radon levels are still above 300 Bq/m<sup>3</sup> then further control measures are required.

*Note: If radon is the sole source of radiation, once radon levels have been reduced to below 300 Bq/m<sup>3</sup> the IRR17 are considered to no longer apply. Successful mitigation therefore removes the employer from the regulatory framework and they should inform the competent authority (HSE) that this is the case.*

## 1.7 Managing radon long-term – where remediation is not successful



**Personal monitoring** for radon: Passive dosimeters worn by individuals to estimate committed effective dose due to exposure to radon and its decay products. These dosimeters are used in rare situations where, although radon levels are elevated, no cost-effective remediation measures are available. This is usually in underground workplaces where staff are required to be classified radiation workers (cat A workers) but can also be used

to assess doses to non-classified workers entering controlled areas. In these cases, individual workers have to be monitored to ensure that their doses are being kept to acceptable levels.

Where it is considered that in the long-term it is not reasonably practicable to restrict exposure entirely using engineering controls (for example, a building with listed status) the customer may in addition use working procedures to restrict exposure. This may include the restriction of access to certain areas.

### **1.8 Workplaces with radon exposure < 6 mSv per year**

The following arrangements must be put in place:

- designate radiation supervised area
- local rules, warning signage and radiation protection supervisor (if appropriate – not usually necessary)
- personal dose assessment (if appropriate – not usually necessary)
- annual three month measurement in highest location(s) is recommended.

### **1.9 Workplaces with radon exposure 6 mSv or greater**

The following arrangements must be put in place:

- special procedures required to restrict exposure (restriction of access/limit of occupancy, or excluding access completely)
- designate a radiation controlled area
- local rules, warning signage and radiation protection supervisor
- classified radiation workers
- assessment of doses from radon exposure
- annual three month measurement in highest location(s).

### **1.10 Prevention**

For new construction, in areas of known elevated radon risk, aim to prevent high radon exposure through the implementation of radon protection measures in new buildings and extensions in areas where high radon levels are more likely. For example, the installation of a membrane that limits radon ingress from the ground. Testing is required within first year of occupation in all new buildings with radon prevention measures to ensure that radon concentration are below action levels.