



**FANC**

FEDERAL AGENCY FOR  
NUCLEAR CONTROL

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*Federal Agency for Nuclear Control  
Department Health & Environment  
Surveillance of the Territory & Natural Radiation*

# OCCUPATIONAL EXPOSURE TO RADON IN BELGIUM

## CONTENT

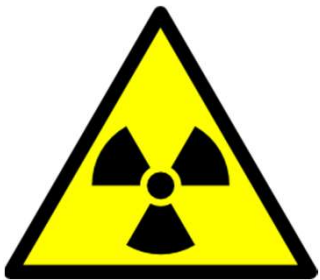
- Properties and health risk
- Dose and exposure
- Situation in Belgium
- Workplace regulations
- National action plan
- How to measure
- Guidance
- Building materials



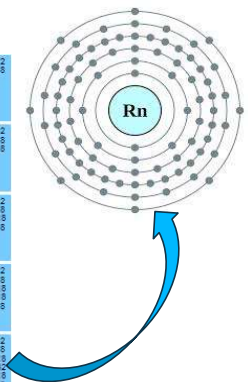
## Properties of radon

### Noble gas

- Natural (from radium and uranium)
- tasteless
- colorless
- No smell
- **Radioactif**

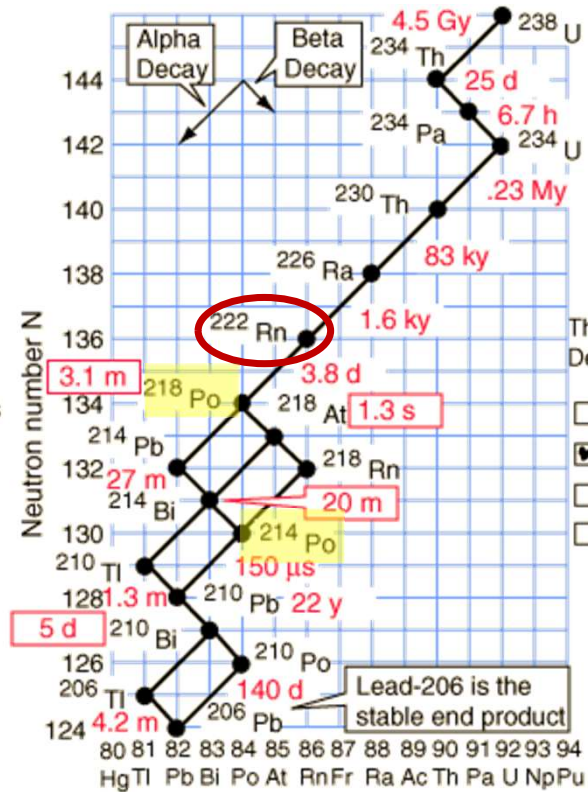


5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.0117	7 <b>N</b> Nitrogen 14.007	8 <b>O</b> Oxygen 15.999	9 <b>F</b> Fluorine 18.998...	10 <b>Ne</b> Neon 20.1797
13 <b>Al</b> Aluminium 26.981...	14 <b>Si</b> Silicon 28.085	15 <b>P</b> Phosphorus 30.973...	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.948
31 <b>Ga</b> Gallium 68.723	32 <b>Ge</b> Germanium 72.63	33 <b>As</b> Arsenic 74.921...	34 <b>Se</b> Selenium 78.971...	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798
49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90...	54 <b>Xe</b> Xenon 131.293
81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98...	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)
113 <b>Uut</b> Ununtrium (284)	114 <b>Fl</b> Flerovium (289)	115 <b>Uup</b> Ununpentium (288)	116 <b>Lv</b> Livermorium (293)	117 <b>Uus</b> Ununseptium (294)	118 <b>Uuo</b> Ununoctium (294)



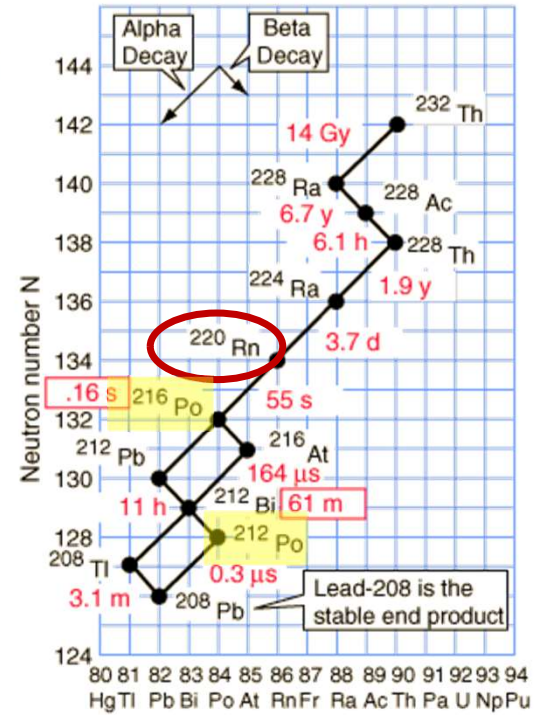
The Uranium-238  
Decay Series

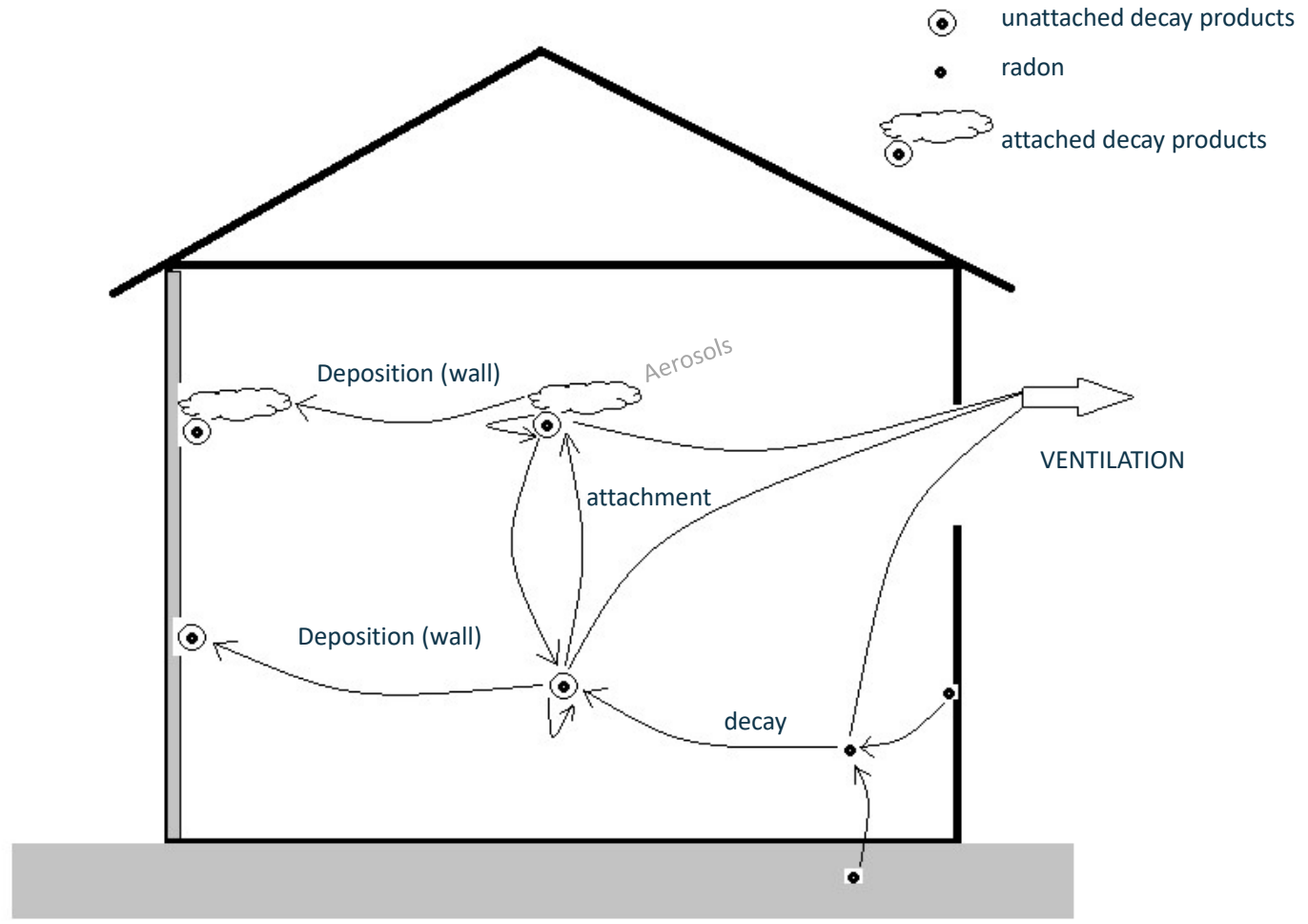
- <sup>235</sup>U Series
- <sup>232</sup>Th Series
- <sup>238</sup>U Series
- <sup>237</sup>Np Series

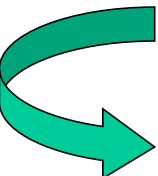
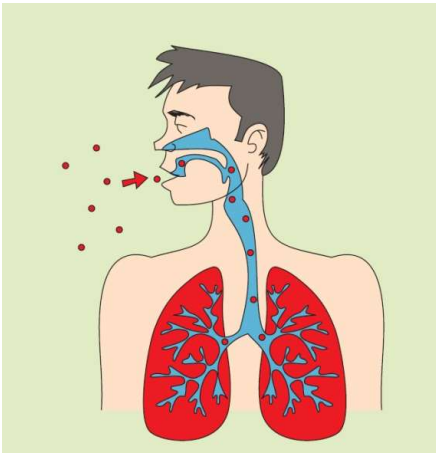


The Thorium-232  
Decay Series

- <sup>235</sup>U Series
- <sup>232</sup>Th Series
- <sup>238</sup>U Series
- <sup>237</sup>Np Series







Radon inhalation increases  
lung cancer risk

- The short-living decay products cause the risk, expressed by the PAEC (potential alpha energy concentration) in  $\text{J}/\text{m}^3$ . This is linked to the Equivalent Equilibrium Concentration:

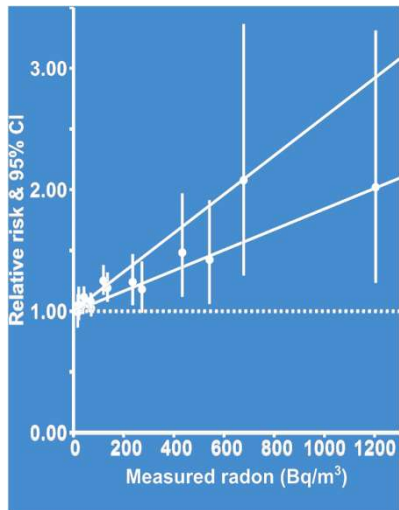
$$EEC = 0,105 * C(^{218}\text{Po}) + 0,515 * C(^{214}\text{Pb}) + 0,380 * C(^{214}\text{Bi})$$

with

$$F = \frac{EEC}{C(\text{Rn})}$$

- $F < 1$  (deposition and ventilation) and = 0,4 in most dwellings, 0,6 in most workplaces.
- There is an attached fraction and an un-attached fraction, the latter penetrating deeper in the lungs

## Large meta-epidemiological study in 13 european countries (1994-2004)



Concentration Radon (Bq/m <sup>3</sup> )	Lung cancers for 1000 NON-smokers	Lung cancers for 1000 smokers
0	4,1	101
100	4,7	116
200	5,4	130
400	6,7	160
800	9,3	216

Darby *et al.*, 2005

# Legal requirements after implementation of 2013/59/Euratom in the Royal Decree on 29/08/2020

- For workplaces
  - obligation to measure in certain workplaces in certain zones (municipalities) => [www.radonatwork.be](http://www.radonatwork.be)
  - Notification (Declaration) if [Rn] > Reference Level RL (300 Bq/m<sup>3</sup>)
  - Corrective measures, dose assessment, mitigation, optimisation
  - Control measures and inspections

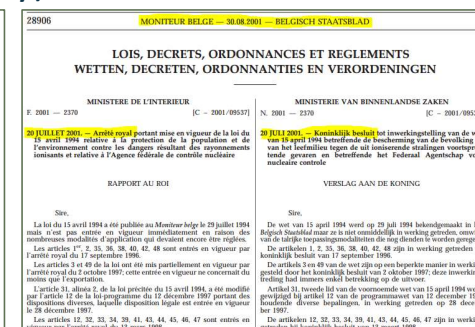


Order detectors  
Guidelines and procedures  
Legislation  
Background information

## Corrective Measures :

- Reduce [Rn] below RL
- Limit exposure below 600 kBq/m<sup>3</sup> or 6 mSv/y

If not possible: planned exposure (follow up and compliance relative to 6 mSv/y)



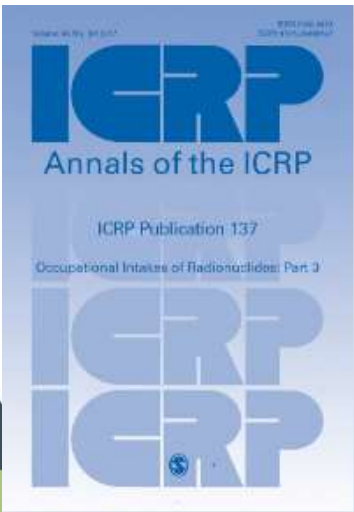
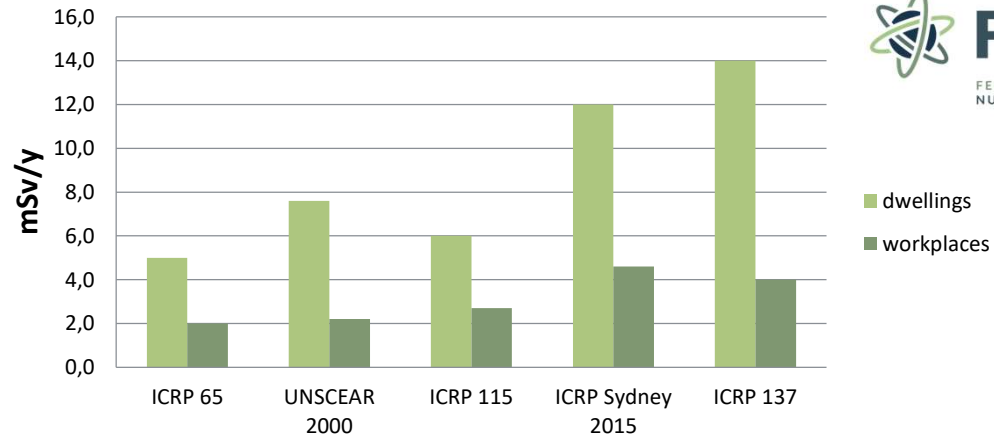


## Dose or exposure?

- General Reference level of 300 Bq/m<sup>3</sup>
- If exceeded:
  - Notification
  - Corrective measures (e.g. air renewal, ventilation, depressurisation, monitoring, calculating exposure)

Dose/exposure levels: Article 20 of the radiation protection Decree: maximal exposure of 600 kBq/m<sup>3</sup> per year, OR 6 mSv/y. For individual RP dose calculations, ICRP 137 have to be used.

300 Bq/m<sup>3</sup>



- (667) In most circumstances, the Commission recommends a dose coefficient of 3 mSv per mJh/m<sup>3</sup> (approximately 10 mSv/WLM).
- (668) In case of substantial physical activities, and for workers in tourist caves, 6 mSv per mJh/m<sup>3</sup> (approximately 20 mSv/WLM).
- (669) Specific aerosol characteristics: if available, calculate site-specific dose coefficients

Reservoir name	Before remediation			After remediation		
	[Rn] average in air (Bq/m <sup>3</sup> )	hours for 600 kBq/m <sup>3</sup>	hours for 6 mSv/y	[Rn] average in air (Bq/m <sup>3</sup> )	hours for 600 kBq/m <sup>3</sup>	hours for 6 mSv/y
Burtonville Laguespré	27536	22	34	10650	56	90
Bèche Salmchâteau	9260	67	105	4231	142	225
Rencheux	1802	333	530	1003	598	950
Grand-Halleux	2633	228	360	1230	488	1950

## Reference Level: graded approach

Bq/m <sup>3</sup>	NEW	existing buildings
600	<i>unacceptable</i>	<i>unacceptable</i>
300	<i>unacceptable</i>	<i>Mostly unacceptable (locally accepted)</i>
100	<p>Reference level</p> <p><i>Optimisation</i></p> <p>Target level</p>	

### WORKPLACES

[www.radonatwork.be](http://www.radonatwork.be)

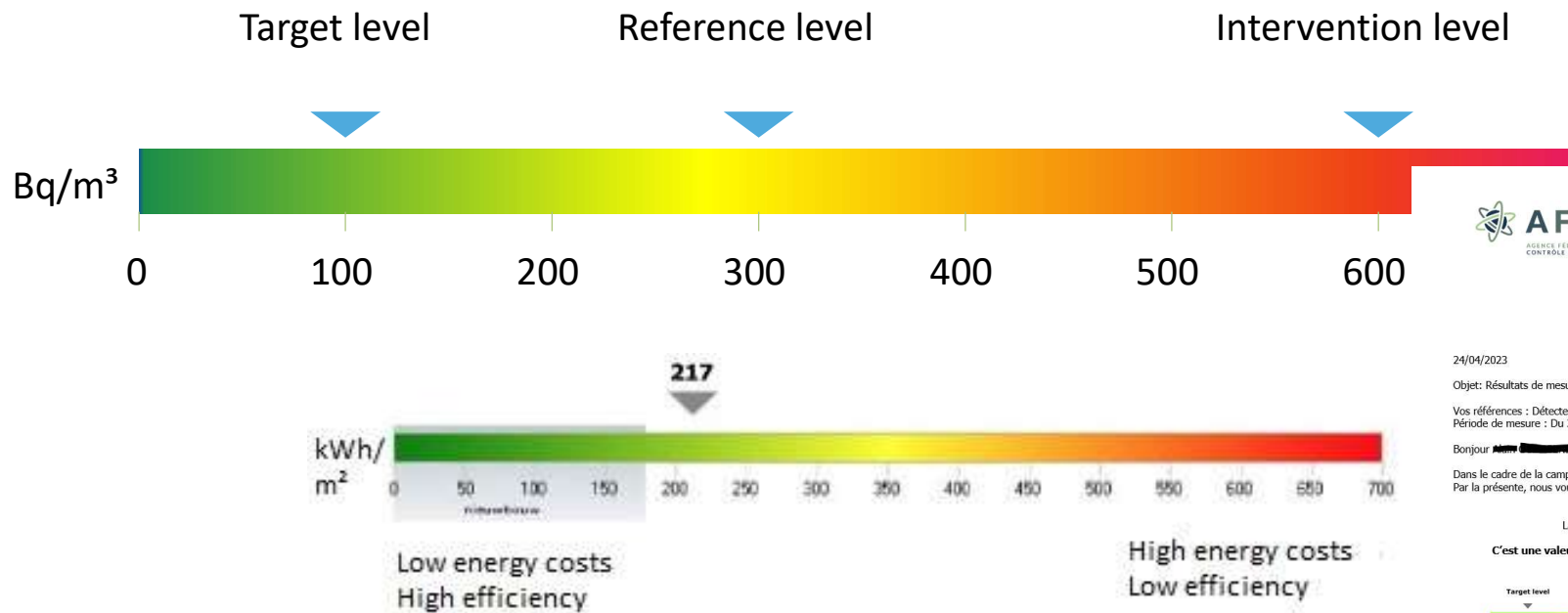
~400 measurements per year

~40 notification files per year

Corrective actions identified

Exposure or dose assessed

Inspections planned/reactive



24/04/2023

Objet: Résultats de mesures radon dans le cadre de l'Action Radon 2022

Vos références : Détecteur REF 10 [redacted]

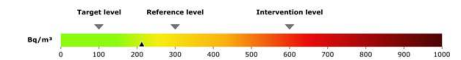
Période de mesure : Du 22/12/2022 au 22/02/2023

Bonjour [redacted]

Dans le cadre de la campagne Action Radon, un capteur radon a été installé chez vous. Par la présente, nous vous communiquons le résultat de cette analyse.

La concentration en radon est de **212 Bq/m<sup>3</sup>**

**C'est une valeur accrue, une action corrective peut être considérée.**



La concentration radon moyenne en Belgique est de 57 Bq/m<sup>3</sup>. En Flandre et à Bruxelles cette valeur est un peu plus basse, à 44 Bq/m<sup>3</sup>.

Des valeurs jusqu'au 100 Bq/m<sup>3</sup> sont considérées comme acceptablement basse, et ne demandent pas de suivi supplémentaire.

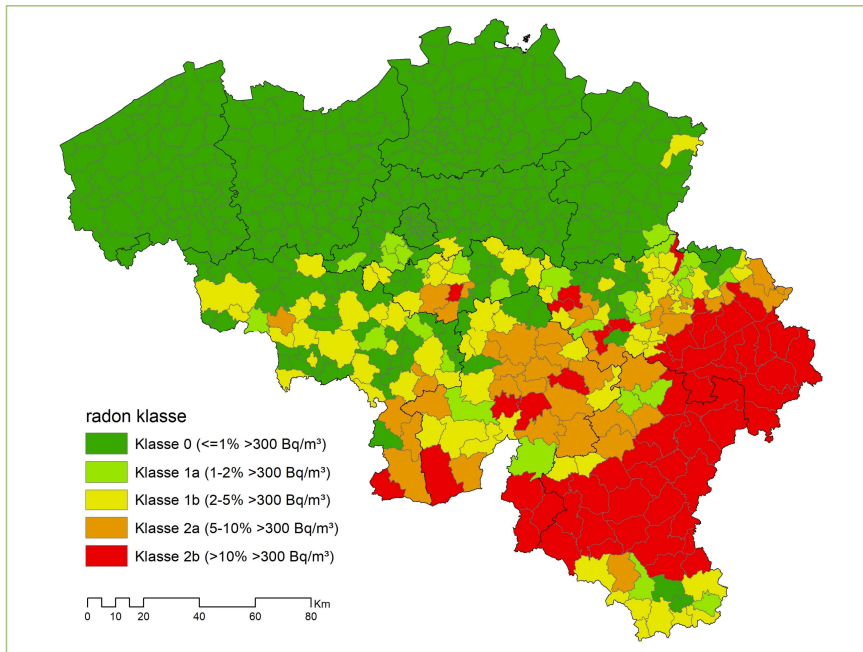
Pour des valeurs au-delà de 300 Bq/m<sup>3</sup>, un suivi est fortement recommandé.

Pour toutes valeurs entre les deux, une évaluation au cas-par-cas d'une remédiation possible doit être faite.

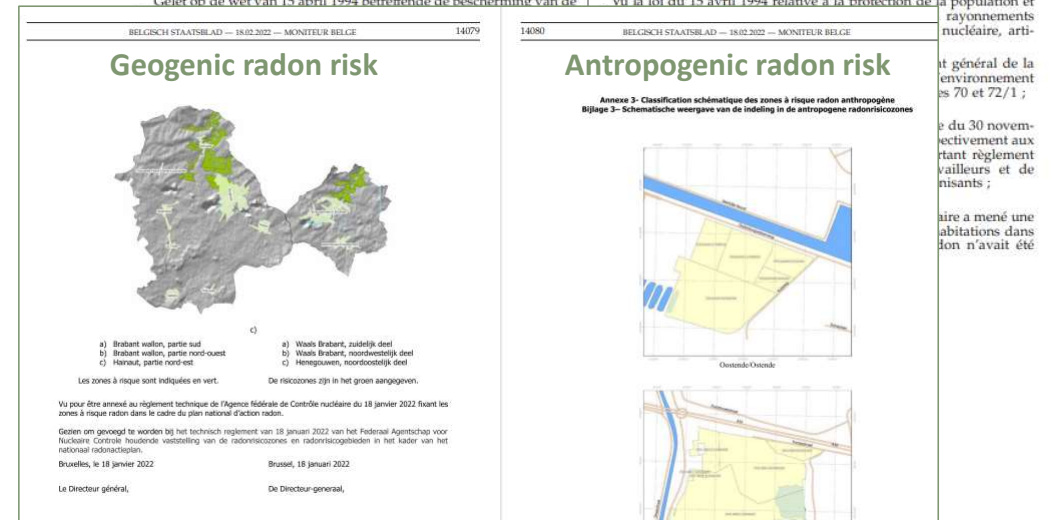
Vous trouvez plus d'infos sur le radon et les méthodes pour diminuer la concentration en radon sur notre site web [Qu'est-ce-que le radon ?](http://Qu'est-ce-que-le-radon-?) | AFCN - Agence fédérale de Contrôle nucléaire ([fnc.gov.be](http://fnc.gov.be)), ou sur le site web de l'action radon [www.actionradon.be](http://www.actionradon.be).

# Radon in Belgium

## FANC Decree classification of the territory in radon classes:



14070	BELGISCH STAATSBLAD — 18.02.2022 — MONITEUR BELGE	14079	BELGISCH STAATSBLAD — 18.02.2022 — MONITEUR BELGE
FEDERAAL AGENTSCHAP VOOR NUCLEAIRE CONTROLE [C – 2022/40059]		AGENCE FEDERALE DE CONTROLE NUCLEAIRE [C – 2022/40059]	
18 JANUARI 2022. — Technisch reglement van het Federaal Agentschap voor nucleaire controle houdende vaststelling van de radonrisicozones en radonrisicogebieden in het kader van het nationaal radonactieplan		18 JANVIER 2022. — Règlement technique de l'Agence fédérale de Contrôle nucléaire fixant les zones à risque radon dans le cadre du plan national d'action radon	
Het Federaal Agentschap voor Nucleaire Controle, Gelet op de wet van 15 april 1994 betreffende de bescherming van de		L'Agence fédérale de Contrôle nucléaire, Vu la loi du 15 avril 1994 relative à la protection de la population et	



- Based on ~40000 indoor ground floor measurements of single-family houses (excluding flats) = conservative statistics
- Legislative purposes:
  - radon region 2 (>5% dwellings > AL (300 Bq/m<sup>3</sup>) radon measurements in workplaces mandatory
  - Graded approach of radon prevention

## Exposure of the Belgian population

	Population	dwellings	AM	Median	GM	GSD	% >100	% >200	%>300	% >400	% >800
Belgium	10584534	3742000	57	44	46	1.7	10.0	2.1	0.9	0.6	0.2
Wallonia	3435879	1325000	84	60	75	1.7	26.0	4.5	2.6	1.6	0.4
Flanders	6117440	2191000	44	37	36	1.2	3.2	0.1	0.05	0.0	0.0
Brussels	1031215	226000	44	37	36	1.2	4.0	0.1	0.1	0.0	0.0
Radon Prone Areas	376568	130000	220	127	137	1.9	43.0	33.0	17.0	13.0	4.3

	dwellings	>100 Bq/m <sup>3</sup>	>200	>300	>400	>800
Belgium	3742000	360000	84000	36000	21000	5600
Wallonia	1325000	280000	79000	35000	21000	5600
Flanders	2191000	70000	some	some	0	0
Brussels	226000	9000	5000	some	0	0
Radon prone areas	130000	56000	43000	22000	17000	5500

## Lung Cancer (LC) Risk due to radon exposure

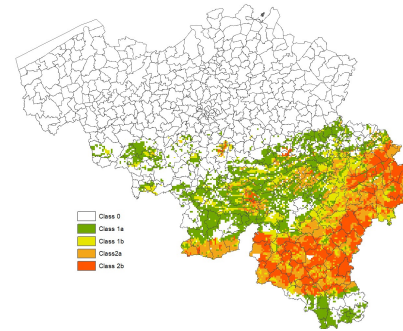
	LC risk NS	LC risk S	LC NS	LC S	total	Due to radon
Belgium	4.4	108.4	399	6558	6958	477 (27 NS and 450 S) (7%)
Wallonia	4.5	113.1	135	2221	2356	252 (14 NS and 238 S) (11%)
Flanders	4.3	107.0	228	3740	3967	222 (13 NS and 209 S) (6%)
Brussels	4.3	107.0	38	630	669	37 (2 NS and 35 S) (6%)
Radon prone areas	5.0	122.0	16	263	279	48 (3 NS and 45 S) (17%)
No radon*	4.1	101.0				

NS = never smokers

S = smokers

## Measuring in workplaces?

- Located in the zones of class 2 (>5% exceed RL)
- Prioritized workplaces:
  - Educational institutes, day-care centres, medical centres
  - Public buildings (post, provinces, municipalities, police, libraries,...)
  - Underground workplaces (galleries and caves open to the public)
  - Water treatment facilities (NORM, EDWD, Radon)



## Current Belgian regulations



GRR-2001

Art. 4.1

- FANC defines the **existing exposure situations** due to radon for which radon exposure has to be measured and **notified** to the regulator body according Art. 9.1
- FANC determines how these **measurements** should be done

FANC technical regulation 18/01/22 defining the **radon prone areas** as part of the national radon action plan



## Current Belgian regulations



GRR-2001

Art. 20.2.2 d)

- *FANC elaborates a reference level*



Fixed in the national radon action plan at 300 Bq/m<sup>3</sup>

### 6.1.1. Reference level

The reference level is defined as the annual average radon concentration above which it is judged inappropriate to allow exposures to occur as a result of that exposure situation, even though it is not a limit that may not be exceeded. The reference level for radon in workplaces (and in dwellings) has been fixed at 300 Bq/m<sup>3</sup>. When reference level is exceeded, a notification has to be submitted to FANC, in application of articles 4, 9 and 20 of the radiation protection regulation (RD 2001). For the workplaces concerned, correctives measures have to be implemented, unless a risk analysis confirms that the maximum exposure level of 600 kBq/m<sup>3</sup> is not exceeded.

## Current Belgian regulations



GRR-2001

Art. 20.3

- *Defines for workplaces the **annual exposure limit to 600 kBq.h.m<sup>-3</sup>** or the **effective dose limit to 6 mSv per year***



Work activities shall be subject either fully or partly to the provisions applicable to **practices** covered by the GRR-2001 if one of those limits is **exceeded**

## Current Belgian regulations



GRR-2001

Art. 72/1.3

- *Describes the radon action plan content and application:*
  - *Strategy for conducting **surveys of indoor radon concentrations or soil gas concentrations***
  - *Approach, data and criteria used for the **delineation of areas***
  - ***Identification of types of workplaces** and buildings with public access where measurements are required*
  - *Basis for the establishment of **reference levels** for dwellings and **workplaces***
  - *Strategy for reducing radon exposure in dwellings*
  - *Strategies for facilitating **post construction remedial action***
  - *Strategy for **preventing radon ingress in new buildings***
  - *Strategy for **communication***

# Belgian National Radon Action Plan



## Belgian National Radon Action Plan 2020-2025

This national radon action plan has been drafted by FANC after consultation and with contributions of the stakeholders.



## OBJECTIVES:

### Long-term:

general **protection** of new buildings  
(design level of 100 Bq/m<sup>3</sup>)

### Short-term:

**remediation** of high levels

Table of Contents	
1. Introduction .....	3
2. Requirements of the European Directive 2013/59/Euratom .....	3
3. Objectives of the radon action plan .....	4
3.1. Introduction .....	4
3.2. Long-term objectives .....	4
3.3. Short-term objectives .....	4
3.4. Graded approach .....	5
3.5. Reviewing of the national radon action plan .....	5
4. Strategy for conducting surveys (measurements) .....	5
5. Classification of the territory in radon classes (mapping) .....	6
6. Regulation of radon risk management .....	7
6.1. Radon risk management in workplaces .....	7
6.1.1. Reference level .....	7
6.1.2. Dose conversion coefficients .....	7
6.1.3. Identification of workplaces .....	8
6.1.4. Corrective measures .....	8
6.1.5. Assignment of responsibilities .....	9
6.2. Radon risk management in dwellings .....	9
6.2.1. Reference level .....	9
6.2.2. Assignment of responsibilities .....	11
6.2.3. Remediation of existing buildings .....	12
6.2.4. Prevention in new buildings .....	12
6.3. Radon from building materials and from drinking water .....	13
7. Raising public awareness, communication and stimulating proactivity .....	13
7.1. Communication Plan .....	13
7.2. Interaction with the indoor air quality programme .....	13
7.3. Public Awareness .....	13
7.4. Training programmes .....	14
7.4.1. Building professionals .....	14
7.4.2. Administrations .....	14
8. Data management .....	14
9. Conclusions .....	15
10. References .....	16
11. Glossary .....	17

[2021-09-22-belgian-national-radon-action-plan-2020-2025-en-v2.pdf \(fgov.be\)](https://www.fgov.be/2021-09-22-belgian-national-radon-action-plan-2020-2025-en-v2.pdf)

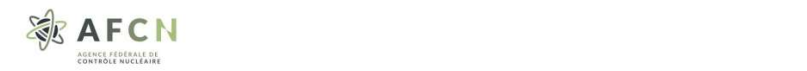
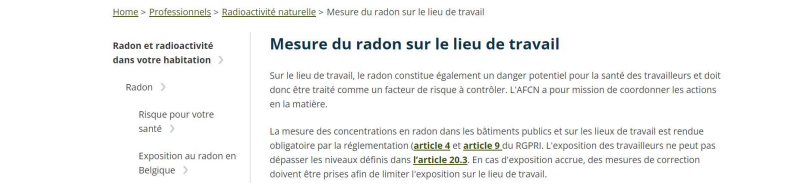
# Guides & tools for employers

Web page (FR/NL) : [Mesure du radon sur le lieu de travail](#)  
| [AFCN - Agence fédérale de Contrôle nucléaire \(fgov.be\)](#)

[Handbook](#) describing all the information needed to carry out radon measurements in the workplace

[Website](#) especially developed for workplaces to make it easier

[Declaration form](#) to use if radon measurements exceed the reference level



## Manuel pour les mesures radon dans les lieux de travail et dans les habitations

L'Agence fédérale de Contrôle nucléaire (AFCN) a pour mission de veiller à ce que la population, les travailleurs et l'environnement soient protégés contre les risques des rayonnements ionisants. En ce qui concerne le radon, le « Règlement général de la protection de la population, des travailleurs et de l'environnement contre le danger des rayonnements ionisants » (RGPR, A.R. du 20 juillet 2001), repris dans le [plan national belge d'action radon](#), stipule que pour certains locaux de travail et les lieux accessibles au public situés dans les zones à risque radon, une analyse de la concentration en radon doit être faite et les résultats doivent être déclarés à l'AFCN dans un dossier de notification. En cas d'exposition accrue, l'AFCN peut imposer des mesures correctives, ce qui doit donner lieu à la limitation des doses reçues par les travailleurs à la suite de l'exposition au radon.

### Campagne de mesure de la concentration en radon dans les lieux de travail

Fiche 1 : Contacts	
<b>Propriétaire</b>	
Nom :	.....
Adresse :	.....
Code postal :	..... Commune : .....
Tél. :	..... Fax : .....
Nom de l'interlocuteur :	..... Prénom : .....
Titre :	.....
Tél. de l'interlocuteur :	..... E.mail : .....
<b>Co-travauteur</b>	
Nom :	.....
Adresse :	.....
Code postal :	..... Commune : .....
Tél. :	..... Fax : .....
Nom de l'interlocuteur :	..... Prénom : .....
Titre :	.....
Tél. de l'interlocuteur :	..... E.mail : .....
<b>Service qui a réalisé les mesures</b>	
Nom :	.....
Adresse :	.....
Code postal :	..... Commune : .....
Tél. :	..... Fax : .....
Nom de l'interlocuteur :	..... Prénom : .....
Titre :	.....
Tél. de l'interlocuteur :	..... E.mail : .....

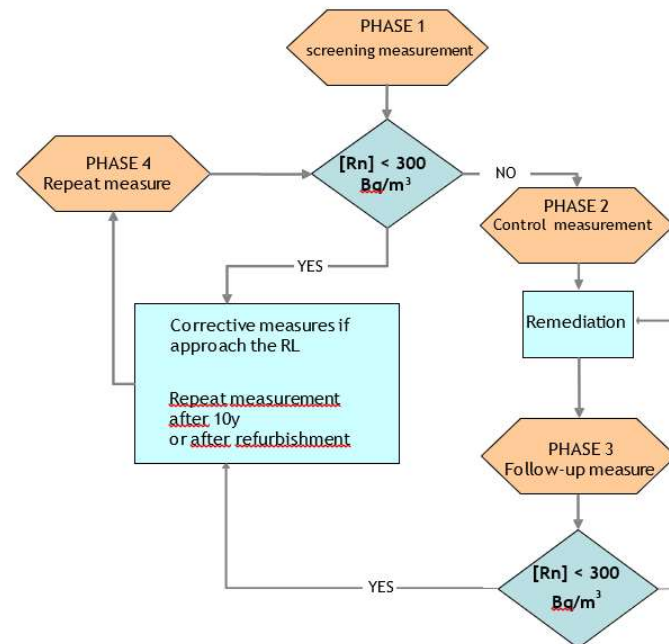
## Measuring What?

Radon measurements in workplaces have to follow a national protocol based on

- Period (heating season between October and April)
- Time (3 months)
- Method (passive SSNTD for initial measurement)
- Location (specific rooms and zones based on the geometry and size of the building)

Type of measurements:

- Screening phase 1
- Control phase 2
- Follow-up phase 3
- Repeat phase 4



# Radon in building materials

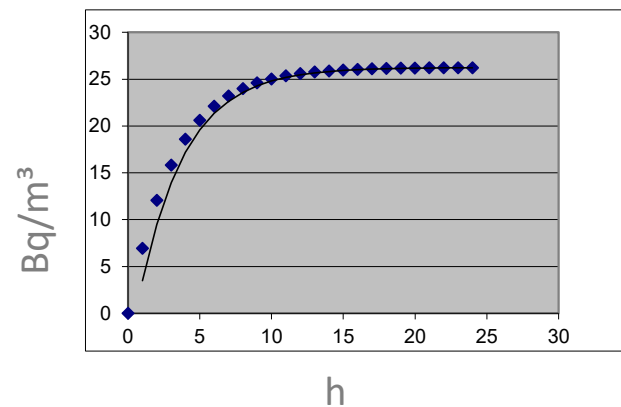


Building materials contain radionuclides (U, Ra, Th, K...en Bq/kg):

bouwmateriaal	Ra-226	Th-232	K-40
beton	20-70	05 tot 40	16-1100
baksteen	10-140	10-130	230-1200
cement	15-100	10 tot 60	50-600
gips	10-300	1 tot 300	20-800
graniet	10-160	10-350	20-2500
caramiek	20-200	30-70	300-1000



Leading to a buildup of concentration:



# Radon in low-energy buildings

## Air-tightness of the building!

### *Blower Door test*

Air changes per hour at pressure difference of 50 Pa:

n50:

~3 h<sup>-1</sup> relatively airtight building

~1 h<sup>-1</sup> strongly airtight building

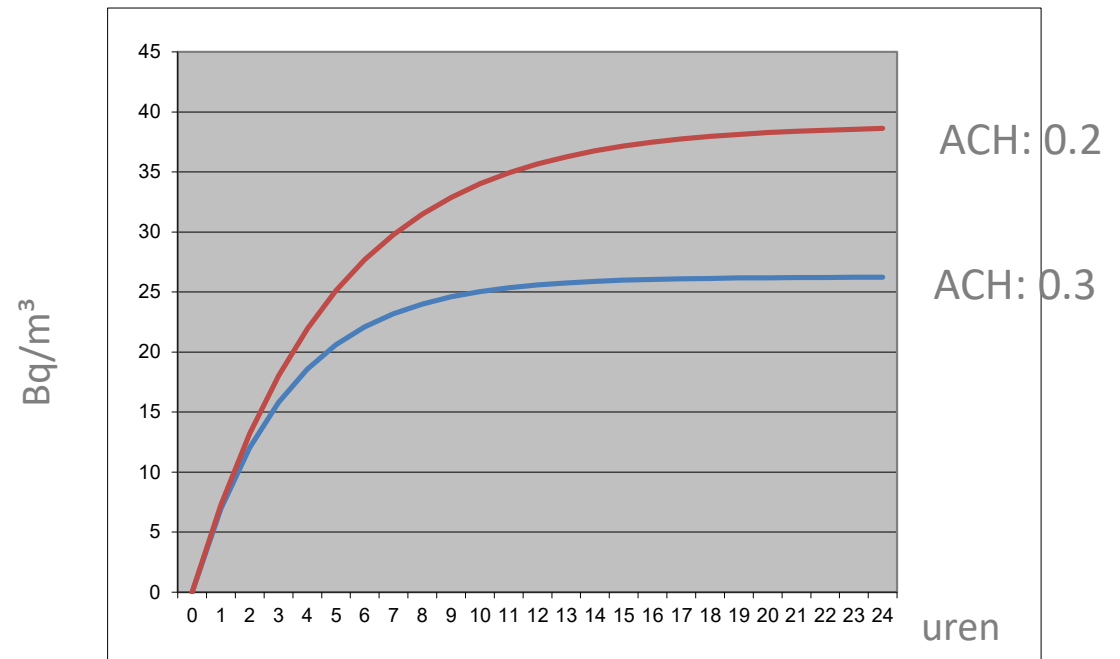
<0.6 h<sup>-1</sup> passive house



Natural air renewal =  
*Blower door 50 Pa/20 (10 to 30)*

$$0.6/20=0.03 \text{ h}^{-1} \text{ (15m}^3 \text{ for 500m}^3\text{)}$$

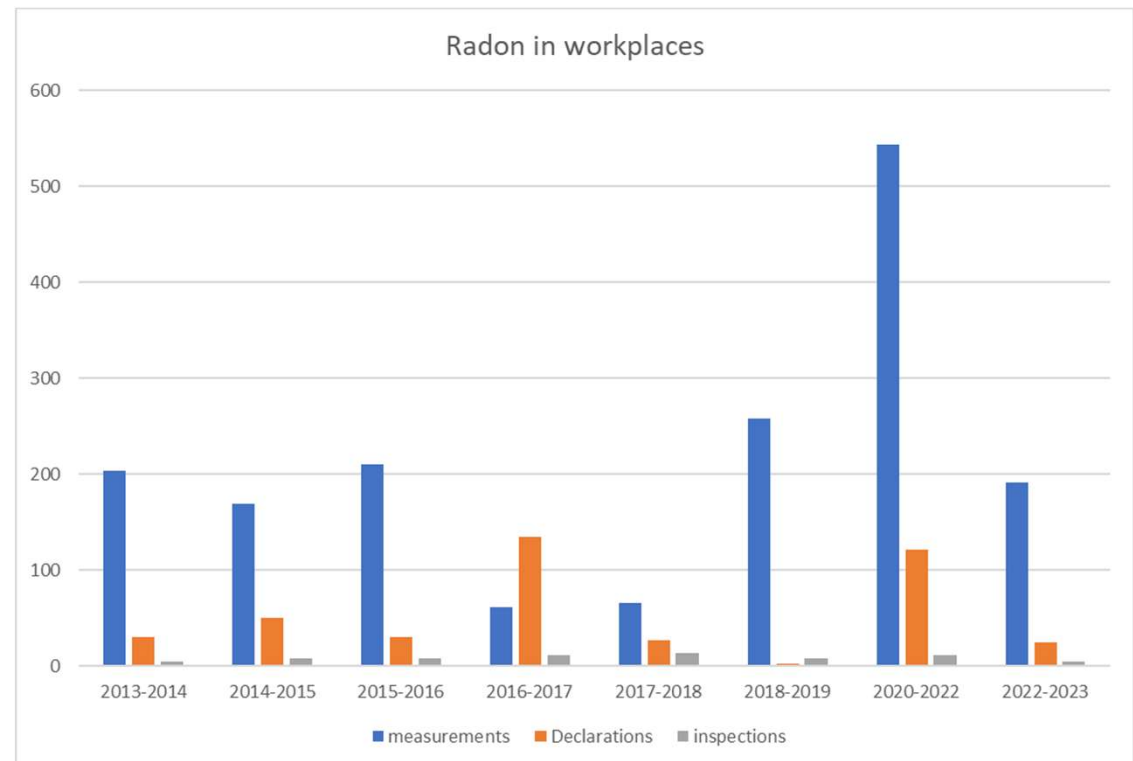
Ventilation is essential!





## In Practice

- Number of workplace measurements: 1703
- Number of notifications: 422
- Number of corrective measures: 422
- Number of licences: 0
- Number of inspections: 72
- Supporting Agencies and collaborations:
  - Prevention Advisors from Internal/External Service for Protection and Prevention at Work: Law on the well-being of workers
  - Associations of such services (for organising campaigns)
  - Labour Inspection (ministry of work)
  - Municipal authorities (department of housing/ department of economy)
  - Trade Unions



## Conclusions

- A graded approach is used in the management of radon in workplaces based on
  - Location (radon classes and related risk)
  - Type of building (with priorities to specific workplaces)
  - Reference levels implying optimisation ALARA above as well as below the RL
  - Special attention to new building protection
- Compliance is assessed based on
  - Providing a maximum of information and guidance through web platforms, documentation in municipalities, relevant agencies and professional environments, training of local actors (administrations, building professionals, health&safety,...)
  - inspection programmes and information- and public awareness campaigns
- Challenge to get collaboration and support from concerned parties such as health and safety prevention, labour inspection, municipal authorities, etc. due to the specific scientific/technical aspects of radon risk management and radiation protection...

Thank you!

