French experience in management and research on the protection of building with respect to radon

Bernard Collignan

Radon Protection Conference, Dresden, 2nd and 3rd of December, 2013
• Presentation of CSTB

• Radon management in France

• Information on building protection

• Examples of research studies

• Conclusion
Scientific and Technical Center for Building: independent French public institution dedicated to innovation in building, of around 900 employees

Public industrial and commercial establishment (known as an EPIC)
It is placed under the joint supervision of Ministry of Housing and the Ministry of Ecology.

Complementary areas:
- Research and innovative technology,
- Evaluation (tests and certification on construction products and processes)
- Knowledge dissemination towards professionals

Large range of disciplines in the field of construction:
acoustic, thermal engineering, lighting, environment, building structure, safety, health, economy, sociology, virtual reality,...

→ contribution to the quality and safety of sustainable construction
Radon Management in France

**French exposure:**

- Medical exposure - 24%
- Radon - 42%
- Radiation from soil - 15%
- Cosmic rays - 10%
- Water and food - 6%
- Other (Nuclear tests and industry) - 3%

Source IRSN

--> Total annual dose: 3.3 mSv

**Risk assessment:**

- Excess risk of lung cancer
- 5-10% of lung cancers attributable to radon: between 1200 and 2900 deaths / year in France
  
  Aggravating factor: tobacco - source InVS

- Public health issue
Measurement campaign in around 12,000 dwellings (DGS/IRSN)

Definition of averaged departmental levels (Bq/m³)

Definition of 31 priority departments for current regulation
Measurements

Example of Radon concentration evolution in a dwelling

Normalisation of screening methodology (NF ISO 11665-8)

- Two months measurement with passive dosimeter in living room during heating season to be representative of annual averaged measurement
- Used in current regulation for screening and control of efficiency of building protection
Current regulation

Existing Public buildings:
Decree of 22 July 2004: rules of risk management in some public buildings

Obligation of radon measurements:
• In the 31 priority departments
• Educational institutions, health and social institutions, jails and spas
• By agencies approved by Nuclear Safety Authority (ASN) (NF ISO 11665-8)

Obligation of implementation of corrective measures

<table>
<thead>
<tr>
<th>Radon concentration</th>
<th>400 Bq/m³</th>
<th>1000 Bq/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>No obligation of corrective measures</td>
<td>Simple measures, technical diagnosis of building, obligation of corrective measures</td>
<td>Short term corrective measures, technical diagnostic of building, obligation of corrective measures</td>
</tr>
</tbody>
</table>
Current regulation

Feed back on measurements in existing Public buildings (2005-2011):

11079 establishments screened including:
- 6735 educational institutions,
- 4301 health and social institutions,
- 20 spas,
- 23 jails.

- Below 400 Bq/m3 - 83.4%
- Between 400 and 1000 Bq/m3 - 12.4%
- Above 1000 Bq/m3 - 4.2%
Current regulation

Underground workplaces:
Decree of 7 August 2008: rules of risk management in some underground workplaces

Obligation of radon measurements:
• In the 31 priority departments
• In the underground places for some professional activities, fixed by decree
• By agencies approved by Nuclear Safety Authority (ASN) (NF ISO 11665-8)

Obligation of action

<table>
<thead>
<tr>
<th>Radon concentration</th>
<th>400 Bq/m³</th>
<th>1000 Bq/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required corrective actions (technical actions, organizational, ...)</td>
<td></td>
<td>Technical actions, individual dosimetric monitoring, atmosphere monitoring, medical surveillance, ...)</td>
</tr>
</tbody>
</table>

Animated by The Nuclear Safety Authority (ASN)

In collaboration with the ministries involved:
- Department of Housing, Urbanism and Landscape (DHUP)
- General Direction of Health (DGS)
- General Direction of Labour (DGT)

And partner organizations:
- Institute for Radiological Protection and Nuclear Safety (IRSN)
- Scientific and Technical Centre for Building (CSTB)
- Health surveillance institute (InVS)

Regional relay:
- Regional Health Agencies (ARS)
- Local Technical centres (CETE)
- Local communities

Developed in continuity of previous plan (2005-2008) and within the logic of:

- The National Health and Environmental Plan (PNSE)
- The second Cancer Plan (2009-2013),
- The Health Work Plan (2010-2014)

Policy objectives:

- New mapping
- Exposure reduction in existing housing
- New rules of construction in new buildings
- Transposition of new Euratom Directive (action level: 300 Bq/m³, impact of building material)

→ Ensure a low level of human exposure.

Success of the plan:

- Membership and collaboration of the various national and local actors,
- Regional initiatives, in the context of Regional Health and Environmental Plan:

→ To strengthen the skill of local actors
→ To make new partners emerge
→ To promote the sharing of expertise
Existing mapping risk management:
Definition of main radon areas but not enough precise for efficient management

IRSN built a new mapping for risk management linking:
Geological nature with cofactors facilitating the transport of radon in rocks and soils (faults, underground mine workings, hydrothermal sites)

→ Future Risk management map?
Under discussions

Radon potential map of geological formations
Map of municipalities affected by radon potential
Radon entry into building

Influence factors

Indoor radon concentration:

- Underlying soil characteristics:
  Nature of the soil, air permeability, presence of cracks or fractures

- Specific building features:
  Nature and state of the basement, air permeability of the building, ventilation level, heating, number of floors of the building, etc..

- Behavior of the occupant.
  Airing (+), heating (-).

Main process: convection generated by depression due to stack effect and wind

Source CSTB
Building protection

Principles:

- Restrict the entry of radon
- Dilute the presence of radon in the building.

Solution Types:

- Sealing the building interface with ground
- Building ventilation
- Treatment of the basement (ventilation, Soil Depressurization System)
New building protection

Systematic approach using Soil Depressurization System (S.D.S.)

Principle of S.D.S.:

- To generate a slight depressurization of basement compared to indoor environment with low extract flow
- Associated with basement sealing
Systematic approach using Soil Depressurization System (S.D.S.)

Principle of preparation of basement:

Examples of treatments for penetrations networks:

**Easy to activate S.D.S. if necessary**
Disparity of situations

Solution protections to implement depend on:

- Level screening measures (NF ISO 11665-8)
- Building characteristics

solutions defined on a case by case basis, could be an iterative process

Appropriate combination:

- Sealing basement interface,
- Building ventilation,
- Treatment of basement

Importance of proper identification of the structure and building systems
Remediation efficiency in existing building

Feedback on the efficiency of solutions implemented in public buildings:

<table>
<thead>
<tr>
<th>Control measurement</th>
<th>Number of cases</th>
<th>%age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 400 Bq/m³</td>
<td>49</td>
<td>40</td>
</tr>
<tr>
<td>Above 400 Bq/m³</td>
<td>73</td>
<td>60</td>
</tr>
<tr>
<td>with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between 400 and 1 000 Bq/m³</td>
<td>57</td>
<td>47</td>
</tr>
<tr>
<td>Above 1 000 Bq/m³</td>
<td>16</td>
<td>13</td>
</tr>
</tbody>
</table>

Levels of measurement controls obtained after remediation compared to the two action thresholds 400 Bq/m³ and 1000 Bq/m³
(122 cases, ASN data)
Feedback on the efficiency of solutions implemented in public buildings:

- Very variable and not always satisfactory
- Radon pathways not always easy to identify.
- Building characterization should be undertaken in a relevant way
- Knowledge of actors not sufficient
Complementary tool for existing buildings

to support the management process of radon reduction in existing buildings

French experimental norm (February 2011):

Referential for technical diagnosis related to the presence of radon in buildings
Mission and methodology (NF X 46-040)

Objectives:

• to identify the causes of radon presence in the building
• to provide the necessary building description for the choice of remediation techniques best suited to the case encountered.

Technical content:

• Undertaken after screening measurement (NF ISO 11665-8),
• Qualitative analysis of building and basement structure, ventilation systems, occupant behaviour, …

Collect of information and building visit:

Geology, Site and building history, climatic conditions, building description, structure, basement, networks, materials, systems (ventilation, heating, …)

Could be completed with:

• Additional radon measurements (NF ISO 11665-8),
• Ventilation measurements
Aim of research:

- To ameliorate building protection
- To help authorities and building actors in risk management

Some topics:

- Test of faisability for S.D.S. in existing building
- Use of existing mechanical ventilation system for S.D.S.
- Experimental study on passive S.D.S and modeling
- Efficiency of mechanical insufflating ventilation
- Building characterisation related to radon entry and exposure
- Impact of thermal rehabilitation on radon exposure
Test of faisability for S.D.S. in existing building

**Principle:**
- To manage a hole on slab,
- To extract air flow from the ground,
- To measure the air flow,
- To measure pressure difference either side of the floor at different points

- Characterisation of air permeability of the ground below the floor
- Mechanical faisability of SDS
- Associated with continuous radon measurement: efficiency of SDS
Test of faisability for S.D.S. in existing building
Test of faisability for S.D.S. in existing building

Radon Protection Conference, Dresden, 2nd and 3rd of December, 2013 | Bernard Collignan
Test of feasibility for S.D.S. in existing building

Installing real system:

Duct in a room

Fan below roof
Test of faisability for S.D.S. in existing building
Test of faisability for S.D.S. in existing building

Mechanical extract flow (m$^3$/h)

Mechanical extraction of technical void
Impact of S.D.S. running on indoor radon concentration

Radon measurement

Test of faisability for S.D.S. in existing building
Use of existing mechanical ventilation system for S.D.S.

Description of Mechanical Exhaust Ventilation Principle in a dwelling

<table>
<thead>
<tr>
<th>Room</th>
<th>Flow Rate (m³/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>45</td>
</tr>
<tr>
<td>Kitchen, high flow, cooking activity</td>
<td>135</td>
</tr>
<tr>
<td>Bathroom</td>
<td>30</td>
</tr>
<tr>
<td>Toilet</td>
<td>30</td>
</tr>
<tr>
<td>Optional other bathroom</td>
<td>30</td>
</tr>
<tr>
<td>Optional other toilet</td>
<td>15</td>
</tr>
</tbody>
</table>

5 living room

Self regulated registers to obtain required exhaust flow
Use of existing mechanical ventilation system for S.D.S.

S.D.S. connexion to the exhaust unit
Use of existing mechanical ventilation system for S.D.S.

S.D.S. connexion to the exhaust unit
## Use of existing mechanical ventilation system for S.D.S.

### Results

<table>
<thead>
<tr>
<th>Dwelling ventilation</th>
<th>S.D.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kitchen exhaust flow (m&lt;sup&gt;3&lt;/sup&gt;/h)</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>Only mechanical ventilation</td>
<td>Low velocity</td>
</tr>
<tr>
<td></td>
<td>High velocity</td>
</tr>
<tr>
<td>Sump with 15 m&lt;sup&gt;3&lt;/sup&gt;/h theoretical register</td>
<td>Low velocity</td>
</tr>
<tr>
<td></td>
<td>High velocity</td>
</tr>
<tr>
<td>Sump with 30 m&lt;sup&gt;3&lt;/sup&gt;/h theoretical register</td>
<td>Low velocity</td>
</tr>
<tr>
<td></td>
<td>High velocity</td>
</tr>
<tr>
<td>Sump connexion with no register</td>
<td>Low velocity</td>
</tr>
<tr>
<td></td>
<td>High velocity</td>
</tr>
</tbody>
</table>

**Kitchen, bathroom and toilet connexion configuration**
Experimental study on passive S.D.S and modeling

One year follow up to assess mechanical efficiency of passive SDS

In situ experimental dwelling

Adaptation of initial sump

- Wind (velocity and direction)
- External temperature
- Internal temperature
- Duct air velocity
- Duct temperature

Basement depressurisation:

ΔP
Experimental study on passive S.D.S and modeling

Evolution of basement extract flow ($Q_{SDS}$) and basement depressurisation

Monthly percentage of running time of SDS above three thresholds
Experimental study on passive S.D.S and modeling

**Modeling:**

to develop an analytical model to determine the mechanical running characteristics of a passive SDS ($Q_{SDS}$ and $P_e$) as a function of building characteristics and meteorological conditions

$$Q_{SDS} = Q_{ind} + Q_{soil}$$
Experimental study on passive S.D.S and modeling

Modeling: confrontation with experimental data

Airflow through SDS duct

Gravel depressurization
Experimental study on passive S.D.S and modeling

Modeling: sensitivity studies

To test and to dimension passive SDS in a given configuration: Building, climate
Efficiency of mechanical insufflating ventilation

Use of mechanical **extraction** for ventilation:
- enhance depressurisation at floor level

Use of mechanical **insufflation** for ventilation:
- diminish depressurisation at floor level

\[
P_{\text{int}}^H = P_{\text{int}}^0 - \rho_{\text{int}} \cdot g \cdot H
\]
\[
P_{\text{ext}}^H = P_{\text{ext}}^0 - \rho_{\text{ext}} \cdot g \cdot H
\]

Indoor and outdoor hydrostatic pressures depending on height of building
Efficiency of mechanical insufflating ventilation

Mechanical insufflation
0.7 vol/h ; + 2 Pa

Mechanical extraction
0.7 vol/h ; -4 Pa

Bq/m³

séjour RdC
Buanderie
Cuisine
Ch. 1
Radim RdC

Mechanical extraction
Mechanical insufflation
Efficiency of mechanical insufflating ventilation
Efficiency of mechanical insufflating ventilation

- Very good efficiency against radon entry
- Cost-effective solution

Potential condensation risk accentuation in walls depending on:
- water vapour production in building,
- meteorological conditions and
- building characteristics.
Building characterisation related to radon entry and exposure

**Context:**

- High variability of indoor radon concentration along time.
- In France in current regulation, radon screening normalised: 2 months measurement during heating period to assess annual averaged indoor radon concentration.
- Difficult to use this protocol in existing dwelling (real estate transaction, occupant behaviour, ...)

**Objective:**

To find an alternative or complementary technique to assess radon potential of a dwelling.
Building characterisation related to radon entry and exposure

**Protocol:**

> Depressurisation of dwelling using blower door

**Principle:**

- For a given depressurisation and mechanical exhaust air (AR) flow of dwelling, analysis of Indoor Rn concentration (measured at the exhaust)

\[ F_{Rn} = C_{Rn}^{\text{asympt.}} \times AR \]

- Test at different depressurisation levels
  \[ \Phi_{Rn} = k \times \Delta P^n \]

\[ C_{Rn}^{\text{asympt.}} \]

\[ \Phi_{Rn} \]

\[ \Delta P \]
Potential for entry of radon building:

\[ P_{\text{Rn4}}: \text{Convective flux of radon under 4 Pa depressurization per square meter of floor} \]

\[ (\text{Bq/s}/\text{m}^2) \]

Protocol tested on 14 dwellings where classical screening had also been realized
Building characterisation related to radon entry and exposure

Tentative of classification:

- \( P_{Rn4} < 0.25 \text{ Bq/s/m}^2 \) → low exposure to radon
- \( 0.25 < P_{Rn4} < 0.65 \text{ Bq/s/m}^2 \) → Medium exposure to radon
- \( P_{Rn4} > 0.65 \text{ Bq/s/m}^2 \) → High exposure to radon

Classification globally in accordance with measurements
Building characterisation related to radon entry and exposure

Numerical assessment of averaged radon concentration:

- Annual calculation using ventilation model and Rn emission law characterised experimentally
- To rebuild annual averaged Rn concentration

Conclusion:
Promising methodology, need to be tested in a larger number of building to be reinforced could be considered as a complementary tool for radon management
Impact of thermal remediation on radon exposure

Data on thermal rehabilitation in France

Often iterative process

Source: Ademe
Impact of thermal remediation on radon exposure

Data from Switzerland:

**Difference in concentration of radon after retrofitting (undifferentiated) for 163 dwellings**

- Averaged before retrofitting: 153 Bq/m³
- Averaged after retrofitting: 193 Bq/m³
- Increase of 40 Bq/m³ (26 %)
Data from Switzerland:

**Difference in concentration of radon after retrofitting (changing windows) for 70 dwellings**

- Averaged before retrofitting: 141 Bq/m$^3$
- Averaged after retrofitting: 191 Bq/m$^3$
- Increase of 50 Bq/m$^3$ (35%)
Numerical study on impact of thermal remediation on radon exposure

Sensitivity study using ventilation model and convective law for radon entry:

<table>
<thead>
<tr>
<th>Airtightness of dwelling</th>
<th>I₄ = 1,6 m³/h/m²</th>
<th>I₄ = 1,2 m³/h/m²</th>
<th>I₄ = 1 m³/h/m² + internal insulation</th>
<th>I₄ = 0,8 m³/h/m² + external insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No ventilation system</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Natural ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference case</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Exhaust Mechanical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ventilation</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Double flux</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Numerical study on impact of thermal remediation on radon exposure

Sensitivity study using ventilation model and convective law for radon entry:

<table>
<thead>
<tr>
<th>Airtightness of dwelling</th>
<th>$I_4 = 1.6 \text{ m}^3/\text{h/m}^2$</th>
<th>$I_4 = 1.2 \text{ m}^3/\text{h/m}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Changing windows</td>
<td>+ internal insulation</td>
</tr>
<tr>
<td>No ventilation system</td>
<td>313</td>
<td>418</td>
</tr>
<tr>
<td>Natural ventilation system</td>
<td>176</td>
<td>220</td>
</tr>
<tr>
<td>Exhaust Mechanical ventilation</td>
<td>153</td>
<td>169</td>
</tr>
<tr>
<td>Double flux</td>
<td>99</td>
<td>110</td>
</tr>
</tbody>
</table>

Radon annual averaged concentration (Bq/m$^3$)
Conclusion

• **Future Challenges:**

  • Development of professional practices for existing and new building to ameliorate protection efficiency

  • **Existing building:**
    Thermal remediation of building and radon exposure

  • **New buildings:**
    Efficiency of ventilation systems and good maintenance along time
Thank you for your attention!

Examples of radon free buildings