LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

TECHNIQUES TO MITIGATE RADON INFILTRATION IN BUILDINGS

Luís Pimentel (LNEC)

Pilar Linares Alamparte (CSIC)

Ana Poças (LNEC)

João Viegas (LNEC)

Illustrations: António Baptista Coelho (LNEC)

The LeaRn4Life project

LeaRn4LIFE
Learning Radon

CO-FUNDED BY THE EUROPEAN UNION

PROJECT NUMBER: 101074516
LEARNING RADON: PROFESSIONAL QUALIFICATION AND SOCIAL AWARENESS AS A STRATEGY FOR REDUCING RADON EXPOSURE

LeaRn4LIFE

Coordination: APA

University of Coimbra (PT)

National Laboratory of Civil Engineering (PT)

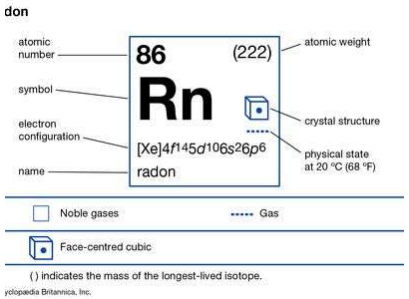
University of Cantabria (SP)

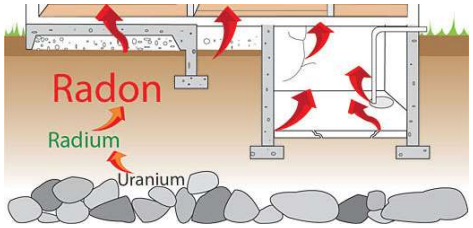
36 months: from August 22 until July 25

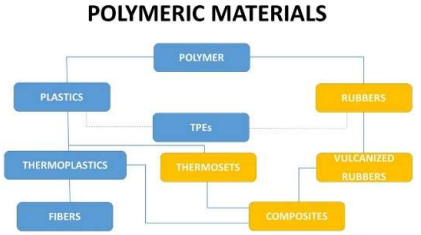
LeaRn4LIFE aims to develop and implement training programs that allow certification and technical qualification in the field of Radon Mitigation in buildings

Organization of the presentation

- Radon
- Influencing factors
- Prevention and remediation
- Materials
- Main remarques and conclusions
- Future challenges and recommendations
- Bibliographic references

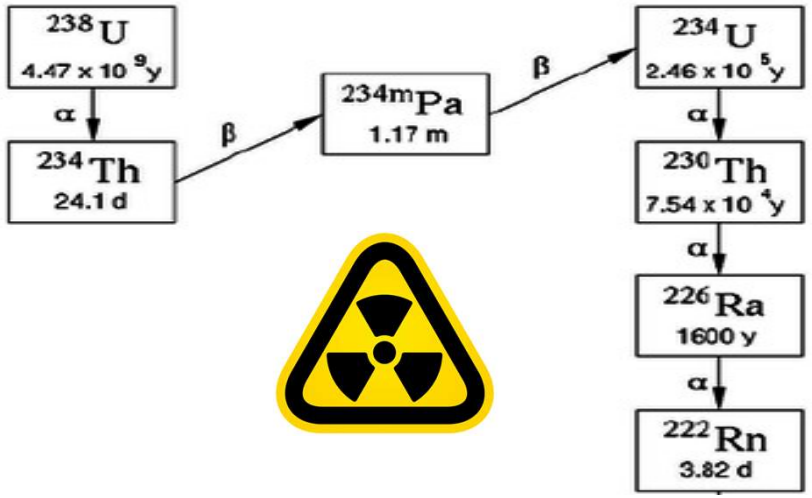






Radon

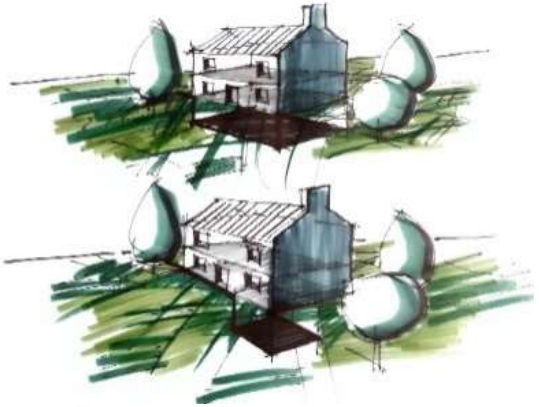
- ✓ Radon (Rn): harmful, colourless, tasteless radioactive gas
- ✓ can be found in granitic soils and rocks as a result of the radioactive decay of uranium and radium.
- ✓ can be present in building materials and water, but in lower concentrations.
- ✓ the greatest natural source of ionizing radiation and exposure of population



- ✓ may enter buildings by convection through cracks and joints or crossing at/between floor and walls (ducts, pipes, cables, etc.) or by diffusion through the envelope itself when it is porous,
- ✓ outdoor Rn exposure is not harmful due to its dilution in the atmosphere, but high levels of concentration of Rn indoors, during prolonged periods can become a public health problem, like lung cancer.

Influencing factors

- ✓ Type of soil (geogenic radon content, permeability and water content)
- ✓ Type of construction and elements in contact with the ground (basements; complete, partial or semi-basements; staggered construction, foundations, spans) [1]
- ✓ Type of ground floors [1]
- ✓ Type of basement walls [1]
- ✓ Type of intermediate floors [1]
- ✓ Ventilation [1], [3]
- ✓ Openings between spaces (doors, stairs, access, barriers); fire safety provisions [1]
- ✓ Climatic factors (temperature, wind direction and velocity, etc.)



Attention: Rn emissions from the materials themselves, joints resulting from the crossing of the slab by various pipes, cracking of floor materials.

Prevention and remediation

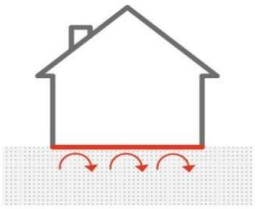
There is a set of solutions that used alone or in combination, depending of the radon potential risk or the measured radon concentration, in new or existing buildings, respectively, allow minimizing the concentration of radon inside buildings

Radon protection solutions can be classified according to the way of action [3]:

1. Insulating habitable rooms from the soil
2. Reducing radon concentration before it enters the building
3. Reducing radon concentration within the areas to be protected

Solutions for the insulation of buildings

Radon barrier

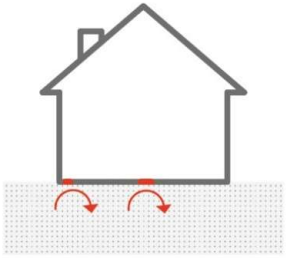


Membrane: laminar element in flexible plastic material or composite, that must allow a limited exhalation of radon, which is a function of both its radon diffusion coefficient and thickness ($Dc < 10 \times 10^{-11}$ m^2 / s and e > 2 mm [4]).

Radon barriers must be:

- sufficiently resistant to the actions they will be subjected to, namely the mechanical actions of puncturing sharp elements
- Applied continuously over the whole envelope, particularly under the internal walls,

Sealing



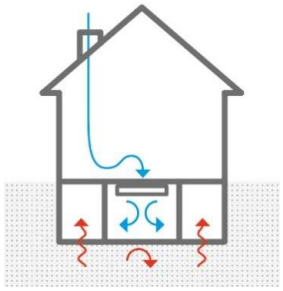
When it is not possible to place a membrane and the envelope does not show widespread cracking or is porous such as a wooden floor, floors and walls may function themselves as a radon protection barrier, sealing fissures, cracks, encounters and joints of these elements.

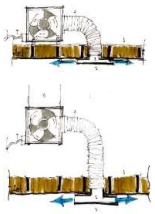
Sufficient when [Rn] in soil < 600 Bq/m^3, but sealing requires complementary measures such as the improvement of the ventilation of habitable spaces, sub-slab depressurization or a ventilated containment space [1], [3]. When [Rn] in soil > 600 Bq/m^3 membranes must be complemented also with these solutions [3] [4].

Solutions for the insulation of buildings

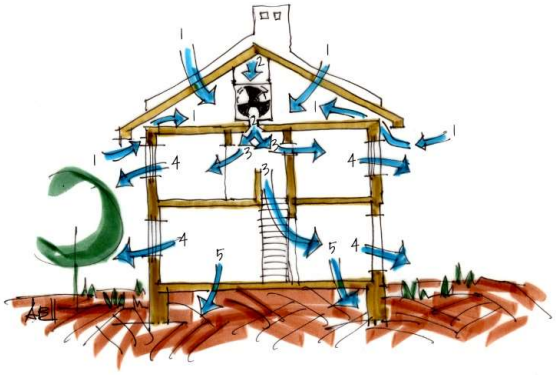
Positive pressurization

Creating a difference in pressure between the air inside the building and the underlying ground, so the natural pressure difference is reversed, by a ventilation unit located in the attic, which is used to blow filtered fresh air into the main rooms (bedrooms and living rooms) of the house, reducing the possibility of radon admission [1], [5].



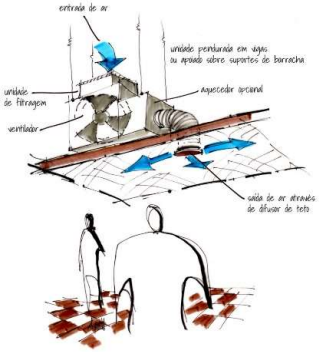


This solution can also be used to protect small habitable areas located in large areas that are not protected, such as, for example, surveillance cabins in garages [3], [4].



[Rn] ≤ 600 Bq/m^3. For higher concentrations, it is recommended to use it in combination with other solutions such as radon barrier or sealing [3].

The effectivity depends on the airtightness of the building envelope, which needs to be high



Solutions for the insulation of buildings

Airtight access doors and hatches

To reducing the air flow from the containment space to the upper floor by reducing the air permeability of the access doors between them.

In the case of improving an existing door, limiting air permeability can be achieved by [3]:

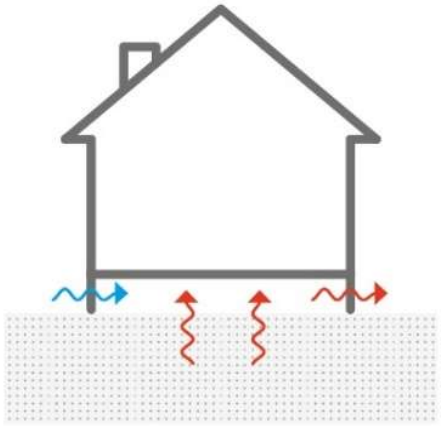
- Placing a self-closing door mechanism
- Placing an elastic joint in the whole perimeter
- Blocking existing ventilation grills

In the case of hatches seldom used, it better to seal it completely. When it is used regularly, the solution will be similar to those of doors.

These solution is not effective enough on its own and should be complemented with other mitigation methods such as radon barrier, sealing or ventilated containment space [3].

Solutions for reducing [Rn] before it enters the building

Ventilated containment spaces

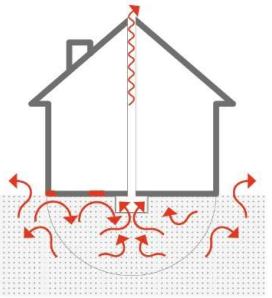


Ventilated spaces such as a crawl space, a cavity wall, an underfloor space or a basement or cellar, may be used to dilute radon that fills this space, difficulting the diffusion of radon towards habitable rooms of the building, performing as containment spaces.

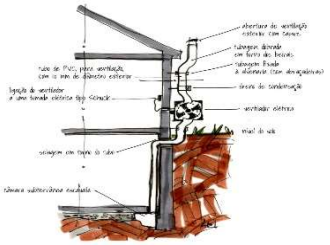
In new buildings, basements, cavity walls ventilated with outdoor air, can be constructed.

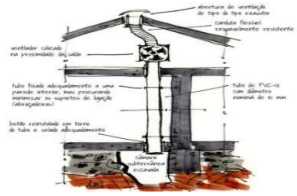
In buildings renovations, such cavities can be added to an existing basement wall when there is enough room for it and it is possible to connect it to the exterior. An aerated floor can also replace completely an existing floor or can be placed over existing slabs if a higher finished floor elevation can be accommodated.

Solutions for reducing [Rn] before it enters the building



Sub-slab depressurization systems





Soil depressurization: most successful protection techniques used to reduce the flow of radon into buildings (for radon levels up to 2,000 Bq/m^3 or higher).

Consists of a single underground sump or multiple sumps, into which exhaust pipes are inserted aiming to suck out the radon-laden air existing in the land, immediately below the ground floor of a building, discharging it harmlessly into the atmosphere [1], [2], [6].

Extraction can be passive, relying on natural stack effect and wind action, or active, with the use of an electric fan, which is a more effective system.

For optimal effectiveness, the permeability of the substrate and the tightness of the enclosure must be high.

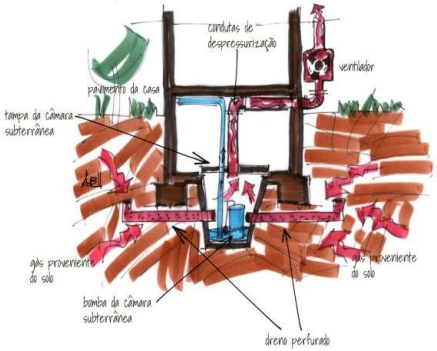
Solutions for reducing [Rn] before it enters the building

Use of drainage systems

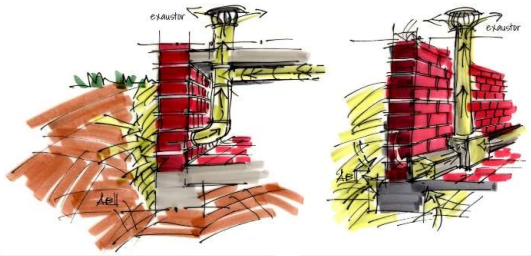
Drainage systems can be used to reduce radon intake in new or in existing buildings, according to one of the following methodologies, [1], [2]:

— Placement of a ventilation duct connected to a fan inserted in a tank for collecting and pumping rainwater from the ground, installed in the basement, exhausting it to an outlet located above the roof of the building.

— Connection of perforated drain pipes, installed under the ground floors, for water drainage, to a ventilation system consisting of ventilation ducts (including exhaust ducts) and mechanical fans.



— Radon aspiration system through the depressurization of the lower area of buried walls formed by perforated bricks or blocks.



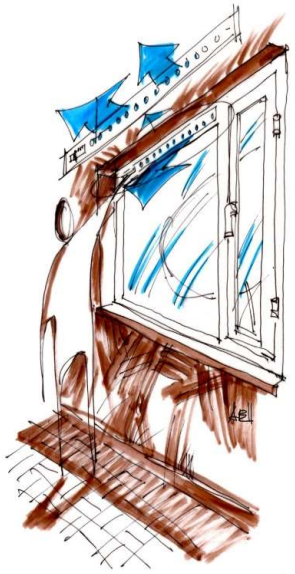
Active systems are more effective than passive systems. The degree of effectiveness of this solution may be like that of underground depressurization systems.

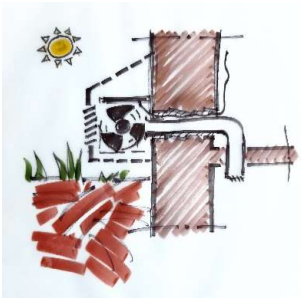
Solutions for reducing [Rn] within the areas to be protected

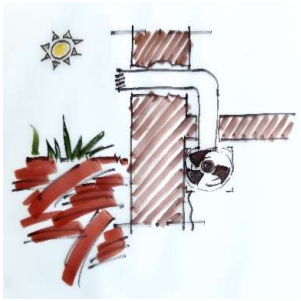
Ventilation of habitable spaces

Indoor natural or mechanical ventilation of habitable rooms.improves indoor air quality and may reduce radon gas concentration. It is effective for [Rn] < 600 Bq/m^3, particularly when is close to 300 Bq/m^3.

It is recommended to complement it with other mitigation methods such as radon barrier, sealing or ventilated containment space.







Materials

Sumps

Prefabricated sumps, made up of plastic material or composites, can be easily and quickly installed under the ground floor of new buildings [2].

Fans

Exhaust fans can be plastic, composite or metal.

Plastic fans are better than metal ones as they have lighter blades and smooth edges, which ensure safety during installation and also do not overload the motor. In addition to this they are more energy efficient, and corrosion and weather resistant.
Fans made up of fiber reinforced plastic (FRP) are highly durable, have a higher strength-to-weight ratio and are lighter than metal fans. In contrast with FRP fans, PVC/polypropylene fans often are a more economical option. Thus, for radon extraction, and not being necessary to work in extremely corrosive environments, with hot fumes or aggressive vapours, PVC or PP fans are better.

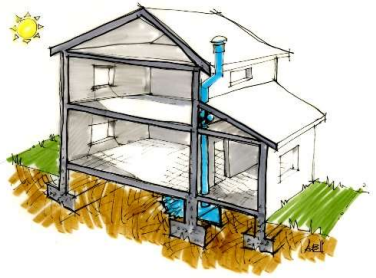
Materials

Exhaust pipes

The exhaust system is usually made up of plastic, usually polyvinylchloride, polyethylene or polypropylene, or composite pipes, because these materials are suitable for radon exhaust as well as for humid environments where metals perform worse.

Plastic and composite materials are also an excellent choice for caps.

Likewise, plastic and composite materials can be used successfully in noise attenuators for air streams containing condensation products.



Drainage systems

The perforated drainage pipes are commonly made up of plastic materials. Underground water reservoirs, which can also be used to extract radon, are also preferably made up of plastic and composite materials, which are more resistant to corrosion in humid environments.

Materials

Barriers

Radon barriers are made up of plastic and composite materials:

- thermoplastic polyolefins (high or low-density polyethylene) with smooth or textured surfaces, consisting of single layer or multilayer.low-density polyethylene that can include metal (generally aluminum) or plastic layers, bituminous membranes modified with atactic polypropylene (APP) or styrene butadiene styrene (SBS), with internal or external reinforced layers.

Sealants

Mastics and polymeric sealants like epoxy or polyester and polyurethane foam (possibly expandable).

Double-sided tape based on acrylic adhesive is mostly used on joints and overlapping zones of membranes.

Sealing sleeves with a self-adhesive ring (based on butyl rubber or an adequate polymeric sealant) must be used around pipes, pillars or columns that pass through membranes.

Main remarques and conclusions

- ✓ **Many of Rn protection measures listed can be routinely installed in new buildings ($ < 2% of building cost), during construction but are more difficult to implement in existing buildings [1], [2], alike in other retrofit implementation measures**
- ✓ **In addition, these solutions are not suitable for all types of buildings, nor for all levels of radon concentration, and in specific cases, it may be necessary to adopt more than one solution to solve the problem of high indoor Rn concentration.**
- ✓ The installation (when possible) of an active system for sub-slab depressurization with or without radon barriers is always the best solution, providing a guaranteed level of effectiveness of up to 2000 Bq/m^3, or even higher than this value in some cases, provided the soil is sufficiently permeable.
- ✓ It is always recommended to install a passive system (natural ventilation), and later, if necessary, convert it into an active system (mechanical ventilation) by installing a fan in the exhaust conduit.
- ✓ **Plastics and composites are the best materials to apply in all solutions**

Future challenges and recommendations

The management of Rn in buildings needs multidisciplinary approaches, from risk perception to technical measures to be implemented.

The most relevant strategic measures, to reduce radon problems, may be classified at various levels, being summarized below:

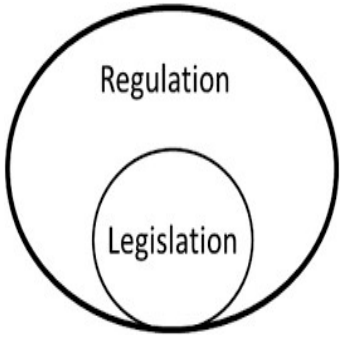
a) **Economic incentives**

- creating financial assistance programs for testing and mitigation;
- creating favorable financing conditions for the construction of radon-resistant buildings;
- stimulating continuous investment in innovation for radon protection technologies;
- promoting and rewarding pioneering innovation on radon technologies;
- reducing VAT for radon products and technologies.

Future challenges and recommendations

b) Regulation and legislation

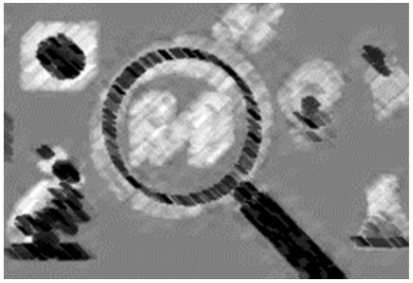
- creating regulations to mandate that all new buildings be built using radon-resistant new construction practices, particularly in radon prone areas;
- supporting radon policy activities;
- supporting the development of indicators of protection efficiency and performance in the construction sector.



c) Research and technological development

- encouraging research and technological development in the area of Rn technologies, particularly in the field of depressurization, range of action of sumps, design and sizing of the system, etc.;

Future challenges and recommendations



c) Research and technological development

—Compiling environmental product declaration data for selected building construction materials and radon protection products.

—developing barriers or outdoor coatings made of nanomaterials to reduce radon diffusion.

—developing solutions based on reverse osmosis, due the fact that exterior paints must prevent Rn from entering while interior paints should allow the escape of gas and vapors which in the meantime are concentrated in the interior environment, in particular in the case of double walls with an air gap.

—increasing the use of recycled and more environmentally friendly materials in protection systems.

—developing prefabricated composite sumps with higher resistance minimizing radioactive components in construction materials, through new compositions.

Future challenges and recommendations

c) Research and technological development

—developing more energy efficient solutions, including the use of lighter and more efficient construction materials, either used in fans or in energy recovery systems.

d) Training and dissemination

—promoting training and training actions, providing workers with knowledge on radon protection systems and how to install them;

—promoting multifaceted communications and public awareness campaigns to improve awareness of radon;

—implementing or increasing radon education at schools.

References

[1] REAL, L. E. P.; LOPES, J. G.; VIEGAS, J, C "**Guia para mitigação da admissão de radão para o interior de edifícios existentes"**. Report 479/2020 – DED/NAICI, LNEC, Lisboa, 143 pp., 2020.

[2] REAL, L. E. P.; LOPES, J. G.; VIEGAS, J, C "**Guia para prevenção da admissão de radão em edifícios novos"**. Report 480/2020 – DED/NAICI, LNEC, Lisboa, 55 pp., 2020.

[3] LINARES-ALEMPARTE, P; GARCÍA-ORTEGA, S. "**Guía de rehabilitación frente al radón**". Ministerio de Transportes, Movilidad y Agenda Urbana y Consejo Superior de Investigaciones Científicas (Ministerio de Ciencia e Innovación). Gobierno de España. Madrid. 2020. ISBN: 978-84-498-1045-9.

[4] Ministerio de Transportes, Movilidad y Agenda Urbana. **Documento Básico de Protección frente a la exposición al radón** (DB HS6). Código Técnico de la Edificación. Madrid. 2019

[5] SCIVYER, C. R "**BRE Good Repair. Guide GRG 37. Part 2 - Radon solutions in homes: positive house ventilation"**. Bracknell, IHS BRE Press, 2013. ISBN 978-1-84806-301-3.

[6] SCIVYER, C. R "**BRE Good Repair. Guide GRG 37. Part 3 - Radon solutions in homes: Radon sump systems**. Bracknell, IHS BRE Press, 2013. ISBN 978-1-84806-302-0.

[7] SCIVYER, C. R.; JAGGS, M. P. R., 1998 – **A BRE guide to radon remedial measures in existing dwellings. Dwellings with cellars and basements**. 1998. BR 343. ISBN 186081 219 8.

END

CO-FUNDED BY THE EUROPEAN UNION

PROJECT NUMBER: 101074516
LEARNING RADON: PROFESSIONAL QUALIFICATION AND SOCIAL AWARENESS AS A STRATEGY FOR REDUCING RADON EXPOSURE

LeaRn4LIFE

This communication was developed under the LeaRn4LIFE Project (Grant Agreement no. 101074516), funded by the European Union.

Views and opinions expressed are, however, those of the authors only and do not necessarily reflect those of the EU or CINEA. Neither the European Union nor CINEA can be held responsible for them.