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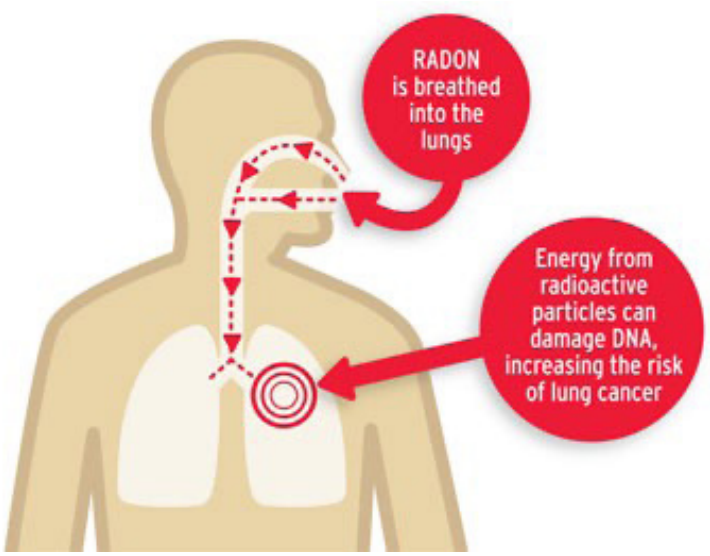
Urban Geology Expert Group

Geohazard: Radon

Radon is a geohazard present in every urban environment, and links directly to human wellbeing.



Radon gas enters the lungs through inhalation.
Source: Environmental Protection Agency (EPA)

Urban Geology plays a key role in understanding and mitigating Radon risks.

What is Radon?

Radon is a radioactive gas, which cannot be seen, smelled, or tasted. Radon is classified as a Class 1 human carcinogen, causing lung cancer. After smoking, radon is considered the second leading cause of lung cancer[1].

Radon (^{222}Rn) is an element which is derived from the decay of the radioactive element uranium (^{238}U) that occurs naturally in rocks and soils. To a given amount (5–20%) radon leaves the rock grains (emanation) and migrates towards the ground surface through cracks and pores in the rocks either as a gas or dissolved in groundwater.

On entering the atmosphere, radon is diluted to very low concentrations but can accumulate in buildings.

Radon originates in minerals within rocks and soil, which vary significantly across the country. Assessing sources and movement pathways of radon in rocks and soils assists with the identification and management of high radon areas. Tectonic faults take on a special role in the evaluation of the radon situation because they can act as migration pathways. In such a situation, very high radon concentrations can occur and be measured in a very localised spatial area of the near-surface.

Does Your House Contain High Radon Concentrations?

Only a reliable building-specific evaluation of the radon situation can be ensured by using appropriate indoor measurements.

Reference Values

The annual residential radon gas concentration should be below the recommended level of 100 Bq/m^3 or lower. If this level cannot be reached the annual mean gas concentration should not exceed 300 Bq/m^3. These reference values are set by the European Directive for Radiation Protection[2] and the World Health Organisation[1]. National variations apply.

This is the most used and recommended radon measure device in Norway. It measures alpha decay activity and gives a mean value of radon concentration over the measured timespan[3].

How does Radon Enter your House?

Radon gas can enter your house from the ground through cracks in walls and floors, gaps in suspended floors and gaps around service (i.e., water, wastewater, heating) pipes. Aggregates used as drainage mass around and under the house may have high concentrations of uranium, and thereby contribute to an increase in radon gas concentrations.

Radon gas concentration is highest in rooms with ground contact, such as basements and cellars. Typically, concentration decreases as the floor levels rise. Even in areas of high ground concentration, levels are lower out of doors due to air dilution.

Facts about Radon:

· The elements uranium (U), thorium (Th) and radium (Ra), which are the source for radon, occur naturally in bedrock and sediments

· In nature, three radon isotopes occur as the decay products of other elements. The element radon ^{222}Rn is the most relevant for radon hazard and the risk of lung cancer[4]

· Radon gas (^{222}Rn) is inhaled and exhaled as a gas. However,the short-lived decay products such as lead (Pb), polonium (Po) and bismuth (Bi), some of which accumulate in aerosols, can remain in the lungs and decay there, damaging them through ionising radiation.

· The half-life of radon is 3.8 days, long enough to migrate the soil and to enter a building

· Radon gas is measured in Bq/m³, Becquerel per cubic metre (1000 litre air). Becquerel is a measure of (radiation) activity and indicates the decay per second. A radon concentration of 100 Bq/m³ indicates that in one cubic meter of air, 100 radon atoms decay per second

· Exposure to high concentrations of radon gas over a long period of time increases the risk of lung cancer. The harmful effect of radon increases linearly to exposure. When the radon gas concentration increases by 100 Bq/m³, the risk of developing lung cancer increases by 16%[1]

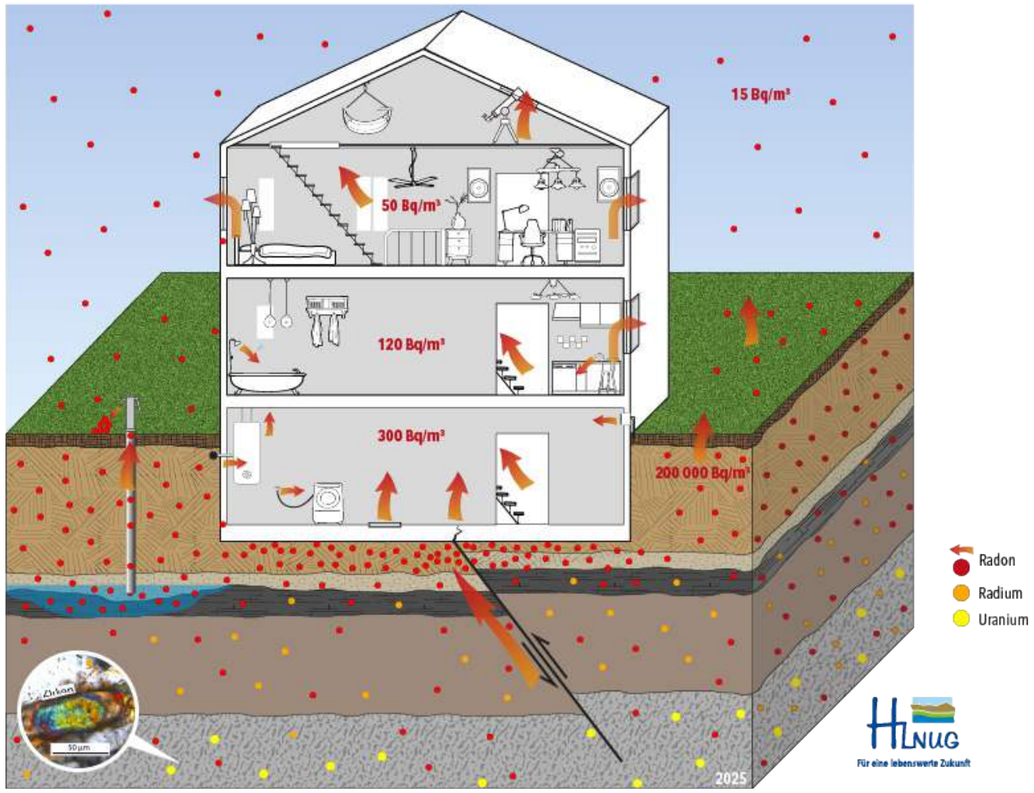
· Epidemiological case-control studies have also shown that this additional lung cancer risk is already significantly detectable at concentrations of around 150 Bq/m³

Facts about Death Rate:

· In Ireland, 56% of the total radiation the citizens are exposed to comes from radon. Approximately 350 cases per year can be directly linked to radon[5]

· In Norway, radon gas is estimated to cause 300 lung cancer deaths per year[6], two to three times high mortality than through traffic accidents (80 in 2021)[7]

· In Germany, about 6.3% of all lung cancer cases, (approximately 2800 per year) are ascribed to radon[8]. This equates to more than 3.5 times the number of fatal accidents at work in 2021[9]



Measures to Reduce Radon Gas Concentrations

There are several measures available to reduce the risk of radon in houses. Firstly, the source of the issue, for example the ground, household water supply building materials and construction aggregates (or a combination of the above) should be identified[6].

Regulations to prevent high radon concentrations in buildings and special building codes are set according to the Euratom-Directive[2]. When constructing new buildings, approved safety measures to prevent radon gas must be installed[10], such as a radon membrane. Similarly, when renovating a building, measures must be considered depending on usage. The Building Regulations of Ireland have similar regulations[11].

Radon and Geology

Radon concentration essentially comes from geology – that is bedrock types with elevated concentrations of uranium (^{238}U), and their derivatives, such as sediments and soils. Radon hazard is a geohazard that intrinsically links geology and human wellbeing.

Bedrock Types that are Known to Contain Higher Concentrations are:

· Acidic igneous rocks, such as granite, and the metamorphic and sedimentary rocks formed from them

· Sedimentary rock with high organic content such as oil, copper and alum shales

· Travertine, a type of limestone, is a source of high doses when used as a building material. Travertine can also cause high concentrations in soils

A very good description of natural radiation (and therefore radon), in a geological context is available in the European Atlas of Natural Radiation[12]. However, radon risk maps are mainly created on a national scale.

When renovating, measures have to be considered depending on the usage.
Source: Mateus Andre

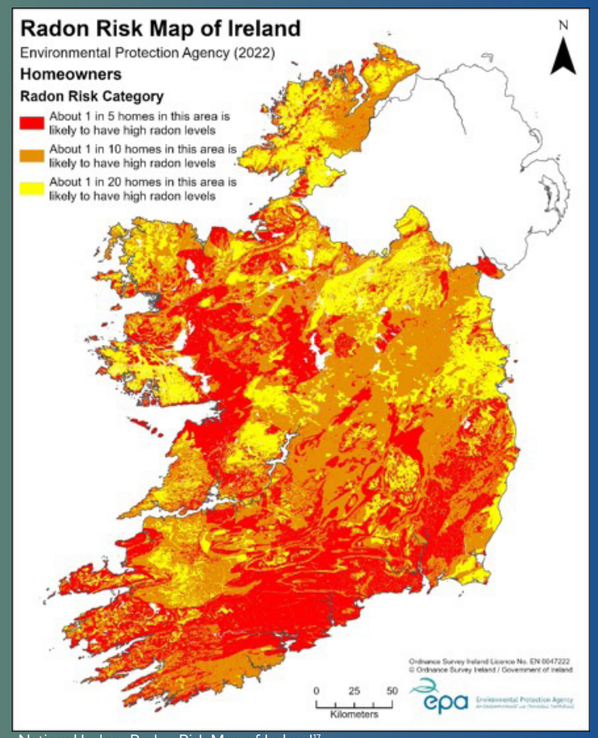
Good Practice

Ireland – Geological Survey Ireland (GSI)[13] provides geological data, modelling and interpretation to help identify areas with high exposure to radon. The Environmental Protection Agency (EPA) provides information on radon testing and remediation as well as collecting data on radon levels in buildings (EPA, 2021).

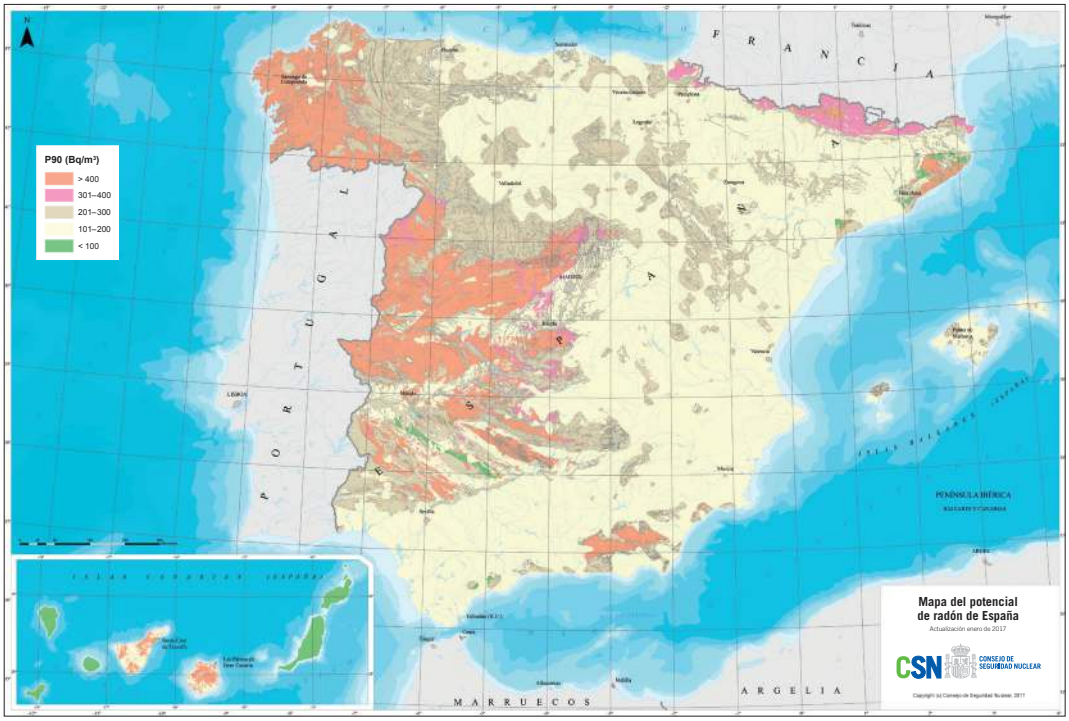
The radon risk map guides the Environmental Protection Agency in prioritising High Radon Areas[5] so they can customise radon awareness and mitigation programmes. The Radiological Protection Act 1991 (Ionising Radiation) Regulations 2019 requires that all workplaces are tested for radon and all new buildings have radon membranes installed. The national Reference Level[5] for long-term exposure to radon in a house, above which the need for remedial action should be considered, is 200 Bq/m³.

Norway – The Norwegian thresholds[6] for indoor radon gas are a recommended level of 100 Bq/m³ and below, and action level at 200 Bq/m³. The National radon risk map of Norway[14] is made in collaboration between the Geological Survey of Norway (NGU) and the Norwegian Radiation and Nuclear Safety Authority (DSA) in 2014, based on geological ground conditions and indoor radon measurements[15].

The Radon Risk Map is a dataset included in the Official Map basis (DOK)[16], and all area planners are instructed by the government to take this into account. Mitigation for radon measures is set by the building code[10].

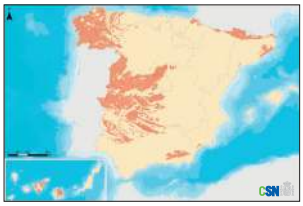


National Indoor Radon Risk Map of Ireland[17].



Cartography of Radon Potential in Spain[18].

ZONAS DE ACTUACIÓN PRIORITARIA



Zonas con potencial de radón (P90) > 300 Bq/m³

En superficie, estas zonas representan el 17% del territorio nacional. Por Comunidad Autónoma, los porcentajes de superficie afectada son: Andalucía, 8%; Aragón 2%; Asturias, 12%; Canarias, 19%; Castilla y León, 19%; Castilla-La Mancha, 10%; Cataluña, 16%; Ceuta, 11%; Extremadura; 47% Galicia, 70%; Madrid; 36%; Murcia, 1%; Navarra, 6%; País Vasco 2%.

ZONIFICACIÓN POR MUNICIPIO

Población en zonas de actuación prioritaria: 0,01%–75% >75%

En color destacado se representan los municipios en los que hay población que reside en zonas de actuación prioritaria. Se muestran en granate aquellos en los que esta población representa más del 75% de la total del municipio.

Good Practice

Spain – The threshold for radon gas concentration is set at 300 Bq/m³, in Spain[18]. The mapping of radon potential in Spain has been developed by the Nuclear Safety Council (CSN) which identifies areas with a significant percentage of residential buildings that have radon concentrations higher than 300 Bq/m³.

The National Radon Hazard Map of Spain[19] is based on 1200 measurements in buildings classified by lithostratigraphy and according to the IGME-CSIC[20]. From this map, a Radon Priority Areas Map is derived, indicating the areas in which more than 10% of the buildings have, on the ground or first floor, radon concentrations above the reference level of 300 Bq/m³. In addition, zonation by municipalities has been assessed, showing the areas with high populations at risk.

Germany – In Germany, machine learning methods were used to generate maps of geogenic radon and to determine the exposure of the population indoors and outdoors[21,22]. Methodology for the German radon map is described by BfS[23] according to the National Radiation Protection Act and the European Commission Directive 2013/59/Euratom[2].

More Knowledge Needed

As radon is present in soil and rock in varying concentrations, urban spaces are inevitably affected, leading to risks due to high population density. As a result, geological information (ideally in 3D) must be made available and include close coordination and cooperation with the relevant authorities, locally and those responsible for radiation protection.

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