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Radon monitoring in public buildings: compliance with the ITACA D.1.5 criterion in Bolzano

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Abstract. Radon represents a significant health risk to indoor air quality in buildings located in radon-prone areas. The ITACA Protocol (criterion D.1.5) establishes strategies to control radon migration from soil, setting the maximum level at 200 Bq/m³ as an annual average value. Monitoring is essential to verify compliance with criteria and ensure healthy indoor environments in public buildings. This study presents radon concentration monitoring in public buildings in Bolzano, an area with radon risk predisposition. The objective is to quantify radon levels in ground-floor and basement spaces, evaluate ITACA compliance, and identify the effectiveness of implemented migration control strategies (passive or active depressurization). The methodology includes continuous annual measurements conducted in lower floor areas with higher occupancy factors, according to ITACA guidelines. Preliminary results demonstrate radon concentration variations across monitored buildings and the effectiveness of adopted mitigation systems. The analysis verifies compliance with ITACA standards (200 Bq/m³) and evaluates migration control strategy performance under alpine climatic conditions. The conclusions provide guidance for achieving optimal ITACA levels, emphasizing the importance of continuous monitoring and integrated strategies.

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1 Introduction

Radon is one of the gaseous pollutants found in indoor environments and has significant implications for the healthiness and quality of indoor air in buildings. This radioactive, odourless and colourless gas is produced by the natural decay of uranium present in the soil and in certain building materials, and represents a major risk factor for human health in confined environments [1]. The danger of radon is linked to its ability to penetrate buildings through foundations and cracks in the underlying soil, accumulating in high concentrations in underground and basement areas, where people spend a lot of time [2]. Prolonged exposure to high concentrations of radon is associated with an increased risk of lung cancer, constituting an internationally recognised public health problem [3]. Public buildings accommodate large and vulnerable populations, including minors, the elderly and people with respiratory diseases, for prolonged periods and with high occupancy rates. The healthiness of indoor environments in public buildings is not only a matter of quality of life, but a fundamental requirement of building sustainability and institutional responsibility [4]. Furthermore, compliance with indoor air quality standards in public buildings is increasingly considered an indicator of the overall sustainability of the structure and administrative management.

At the European level, EURATOM Directive 2013/59 (Official Journal of the European Union, 2013) [5] established the regulatory framework for protection against ionising radiation, setting a maximum action level for radon at 300 Bq/m^3 as an annual average in living and working environments. In Italy, this regulatory requirement has been transposed and further supplemented with more stringent criteria through building sustainability assessment tools, in particular the ITACA Protocol (Institute for Innovation and Transparency in Procurement and Environmental Compatibility) [6].

Criterion D.1.5 of the ITACA Protocol [7]- specifically dedicated to radon control in buildings - imposes a maximum limit of 200 Bq/m^3 as an annual average value, representing a more stringent environmental sustainability standard than that required by European legislation. The same value (200 Bq/m^3) is also required for public buildings (CAM Edilizia- [8] which, among the mitigation approaches considered useful, explicitly includes targeted ventilation systems aimed at modifying the pressure differential between the indoor and outdoor environments of the building. Moreover, the CAM Edilizia applies to refurbishment and new-build interventions regardless of whether the building is located within radon-priority areas identified under Article 11 of Legislative Decree 101/2020, and it requires post-intervention monitoring of the annual average indoor radon concentration in accordance with Legislative Decree 101/2020 [9]. The same value (200 Bq/m^3) is also required for residential buildings constructed from 1 January 2025.

The ITACA Protocol criterion does not merely define the limit value, but prescribes a comprehensive control strategy that includes: (1) the planning and design of strategies to reduce radon migration; (2) the implementation of active (depressurisation with forced ventilation) or passive (natural depressurisation) mitigation systems; (3) the execution of continuous monitoring campaigns of radon concentration on an annual basis, focusing on ground floors and basements where the concentration is on average higher [10].

The ITACA Protocol is now a recognised standard for the certification of environmental sustainability in buildings in Italy and represents an important evolution in the approach to building quality, integrating technical, regulatory and health-oriented design aspects [11]. Compliance with criterion D.1.5 has become an increasing priority in the design and construction specifications for public buildings, as it is related to both health requirements and urban sustainability policies.

The Province of Bolzano is characterised by a significant geographical and geological predisposition to radon risk. The geological structure of the Province and the types of housing (buildings on slopes with greater horizontal and vertical exposure) favour the presence of radon in buildings. The alpine climate, characterised by long, cold winters with significant variations in atmospheric pressure, also favours the influx of radon into buildings through the differential pressure gradients between the interior and exterior. Systematic monitoring of radon in public buildings in the Province has been organised on a centralised basis, starting with school buildings.

This paper is organised as follows: Section 2 presents the regulatory framework and ITACA criteria; Section 3 describes in detail the monitoring methodology adopted; Section 4 presents the preliminary results of radon concentration and conformity assessment; finally, Section 5 provides conclusions and recommendations for achieving healthy and resilient environments in public buildings in Bolzano.

2 ITACA Protocol

ITACA Protocol is an Italian multicriteria tool for assessing the environmental sustainability of buildings. Developed and promoted by the Institute for Innovation and Transparency of Procurement and Environmental Compatibility (ITACA), it serves as a technical tool to evaluate the environmental quality of buildings throughout their entire lifecycle from design and construction to use and eventual demolition or disassembly. ITACA Protocol is based on SBTool, an international framework for rating the sustainable performance of buildings and projects developed by iiSBE, a non-profit global organization whose aim is to promote the adoption of policies and tools for a sustainable built environment.

Since 2015 ITACA Protocol has become a national standard, UNI Reference Practice (RP) 13, in force to a collaboration between ITACA and UNI which is the Italian body for standardization.

ITACA Protocol – UNI RP 13 assesses the environmental sustainability of buildings through an evaluation process organized into hierarchical levels: Areas, Categories, and Criteria.

Areas are the main themes that define the sustainability characteristics of a building. Each Area is divided into Categories, which group related Criteria. Criteria are specific aspects that can be measured to determine environmental performance. For example, within "Resources Consumption," criteria might include energy efficiency, water usage, and material sourcing. In the present version ITACA Protocol – UNI RP 13 is divided in the following 6 Areas of evaluation:

[1] Site Quality: Evaluates the location and integration of the building with its surroundings;
[2] Resources Consumption: Assesses the use of energy, water, and materials;
[3] Environmental Loads: Measures the environmental impact, such as emissions and waste;
[4] Indoor Environmental Quality: Focuses on health, comfort, and well-being inside the building;
[5] Service Quality: Considers the functionality and services provided by the building;
[6] Adaptation to Climate Change: gives an evaluation on the permeability of the surroundings of the building and heat island effect.

The overall assessment of a building is given by a final score that considers the results obtained for each criterion. The scores for the criteria are then combined to obtain a final result. Each criterion is assigned a score between -1 and +5: 0 represents the reference value (regulatory limits or typically acceptable practice), positive scores indicate performance above the reference value, and negative scores indicate that the building is below the reference value. Scores are weighted according to the importance of each criterion and category.

The final score is calculated by multiplying the score for each criterion by its weight, adding the scores within the categories, then weighing and adding the categories within the areas, and finally aggregating all areas to obtain an overall score for the building.

This multicriteria, weighted and holistic approach allows for a nuanced and comprehensive assessment of sustainability, encouraging innovation and the use of sustainable materials and practices. Alignment with regulatory standards ensures that buildings not only aim for high performance but also comply with regulatory requirements.

2.1 Criterion D.5.1

The six main assessment areas comprise approximately 40 criteria, depending on the type of building being assessed. Criterion D.5.1 “Radon” falls within area D, relating to “Indoor environmental quality”. This area typically covers aspects that affect the health and comfort of building occupants, such as air quality, lighting, acoustics and the presence of hazardous substances such as radon.

The environmental objective of the criterion is to minimize exposure to radon by controlling its migration from the ground into indoor environments. A performance indicator is used to assess the building's performance, evaluating the presence of design strategies for controlling radon migration. In addition to design strategies, radon level measurement is mandatory for public buildings.

The verification method is based on the characteristics of the design solutions adopted to control radon gas migration within the building.

The main systems for reducing radon in new buildings are:

- passive depressurization system under the floor slab or under the membrane between the floor slab and the ground;

- active depressurization system under the floor slab or under the membrane between the floor slab and the ground.

Criterion D.5.1 also assesses the implementation of remediation measures, such as preventive protection measures for new buildings, which must be designed to eliminate or at least significantly reduce radon migration into buildings due to negative pressure in inhabited rooms. The measures can generally be divided into:

- elimination of factors that generate negative pressure in inhabited rooms;
- depressurization of the area below the building;
- generation of artificial overpressure in the building;
- expulsion of radon-rich air from the basement by ventilation;
- expulsion of radon-rich air from living spaces by ventilation and/or air filtration;
- insulation and sealing.

Once the design strategies and remediation measures used in the building have been assessed, a score can be assigned to the criterion. The assessment scale is based on different scenarios that describe the situation found in the building or project. Once the scenario that best describes the characteristics of the planned or completed interventions has been identified, the corresponding score is assigned.

2.2 Criterion D.5.1: update proposals

Below are some proposed amendments to criterion D.5.1, which will be updated during 2026:

- Update of legislative references: National Radon Action Plan (PNAR) for the definition of radon strategies, both as prevention and remediation techniques
- Update of legislative references: CAM Edilizia 2025 edition, in force from February 2026 for public buildings (residential, schools, offices)
- Differentiation of criteria between new buildings (prevention techniques) and existing buildings (monitoring and then remediation techniques)
- Confirmation of the reference level of 200 Bq/m^3: this is a voluntary requirement of higher quality than the regulatory limit of 300 Bq/m^3 (for workplaces and residential buildings constructed before 1 January 2025).
- Correlation between the issue of radon and energy efficiency strategies. The two issues must be addressed together.

3 MONITORING METHODOLOGY

In line with ISO 11665-8 [12], the international standard that defines the methodology for assessing indoor radon-222 concentrations in buildings, the radon assessment strategy was structured as a stepwise process aimed at estimating the annual average radon activity concentration for compliance verification (ITACA D.1.5 reference level). The analysis and measurement strategies for radon assessment aim to determine the sources, the most critical issues and, for workplaces, to comply with legal requirements, and include:

Pre-intervention monitoring (passive, integrated measurements) – initial investigation:

long-term integrated measurements, compliant with ISO 11665-4 [13], were performed to approximate the annual average radon activity concentration in the building. Measuring points were defined by homogeneous zones (same soil–building interface, ventilation regime and temperature conditions), prioritising ground-contact and lower levels. At least one detector per selected homogeneous zone was installed. Detectors were positioned in occupied rooms, under normal use conditions, at 1–2 m above the floor, avoiding non-representative areas (e.g., entrances, transit zones, etc.). The exposure duration was longer than two months, with at least half of the measurement period during the winter/heating season, to minimise the risk of underestimation.

Pre-intervention monitoring (active loggers, continuous measurements at hourly intervals) – additional investigations / diagnostic support: where passive results indicated elevated concentrations, continuous measurements (e.g., hourly logging) were used to characterise short-term variability and the influence of occupancy patterns, heating and ventilation settings, over at least a day–night cycle. Continuous monitoring was combined, where relevant, with short-term screening/mapping activities to support the identification of critical rooms, suspected entry routes (cracks, service penetrations, piping runs) and inter-room transfer pathways, recognising that these measurements are primarily diagnostic and not representative of the annual average.

Pilot mitigation installation (pilot plant): a pilot mitigation solution was implemented in the most critical area identified during the diagnostic phase (e.g., a decentralised CMV system). The pilot intervention was designed to provide operational evidence for the selection and scaling of the final remediation strategy.

Post-intervention monitoring (verification and follow-up) – passive and active measures: the effectiveness of the implemented mitigation was verified by repeating the initial investigation approach (passive, long-term integrated measurements), with a new definition of homogeneous zones and measurements extended to the entire building, not only previously critical rooms, to account for potential redistribution effects. In parallel, continuous hourly monitoring was used to confirm the operational stability of active systems and to document performance under routine building use. Periodic follow-up measurements were planned to assess the sustainability of the mitigation over time and after significant changes in ventilation conditions.

3.1 CASE STUDY

The methodology described above was applied to the case study presented. The subject of this study is a public office building located in Bolzano. Following annual passive measurements, exceedances of the reference level were found in some rooms in the basement. These were remediated by installing a decentralised CMV system in a pilot office. Radon levels in the pilot office were significantly reduced, and based on the results, the ventilation rates and design of the meeting room next to the remediated office were evaluated (Fig. 1).

Fig. 1. Photographs of the two renovated rooms. On the left is the office and on the right is the meeting room.

4 RESULTS

The monitoring results expressed as monthly averages are shown in Tables 1 and 2.

Table 1. Comparison of radon concentrations in three rooms. The VMC was installed in the office in October 2024.

Radon (Bq/m^3)	Meeting room	Office with VMC	Archive
July 2024	625	512	-
October 2024	817	118	329
Percentage change	+30%	-77%	-

Table 2. Comparison of radon concentrations in three rooms. In the meeting room, the VMC was installed in the summer of 2025.

Radon (Bq/m^3)	Meeting room with VMC	Office with VMC	Archive
October 2024	817	118	329
November 2025	188*	52	250
Percentage change	-77%	-55%	-24%

* working hours

For the case study analysed, the score for criterion D.5.1 of the ITACA Protocol is 3 (public building, "good" rating) and the average annual concentration is less than 200 Bq/m^3.

Radon monitoring shows a marked decrease in concentrations in the office after installing the VMC, from 512 to 118 Bq/m^3 (–77%). In the meeting room, the introduction of VMC reduced radon from 817 to 188 Bq/m^3 during working hours, again corresponding to a 77% reduction. The combined data clearly indicate that mechanical ventilation is the main driver of radon reduction in the monitored rooms.

For the considered case study, the score of 3 for criterion D.5.1 of the ITACA Protocol places the building in the "good" performance class for radon control.

Importantly, the resulting average annual radon concentration in all monitored spaces is now below 200 Bq/m^3, aligning with best-practice targets and supporting a satisfactory level of indoor health protection.

5 CONCLUSIONS

The analysis of radon management in public buildings located in radon-prone areas highlights the need for an integrated, long-term strategy that combines prevention, monitoring and mitigation within a unified sustainability framework. In this perspective, the ITACA Protocol – and in particular criterion D.5.1 – provides a useful operational reference for aligning indoor air quality objectives with broader environmental and regulatory requirements. Future developments in this field can be expected along several converging trends: the first is the stronger integration between energy efficiency and radon control. Increasingly airtight building envelopes and advanced energy retrofit strategies will require systematic coordination with radon prevention and mitigation, to avoid unintended accumulation of indoor pollutants. Design tools and certification schemes will likely incorporate coupled indicators for ventilation performance, airtightness and radon.

The second trend is the differentiated approaches for new and existing buildings. Prevention will become standard in new constructions, through predisposition for sub-slab depressurisation, robust detailing at the soil–building interface and integrated mechanical ventilation strategies. In existing public buildings, progressive programmes based on screening, targeted monitoring and stepwise remediation will remain essential.

Another trend is the evolution of regulatory and voluntary frameworks. The progressive alignment of national legislation, the National Radon Action Plan, CAM Edilizia and updated versions of ITACA will tend to consolidate reference levels, standardise monitoring protocols and strengthen requirements for post-intervention verification. Voluntary schemes are expected to maintain more ambitious targets than minimum legal thresholds, particularly for sensitive public buildings.

Last trend is wider use of continuous and smart monitoring. The deployment of compact, connected sensors and building management systems will facilitate continuous tracking of radon levels, automatic logging of data and integration with HVAC controls.

This will support adaptive operation of mitigation systems and enable more robust, data-driven compliance with annual reference levels.

Within this evolving scenario, the role of protocols such as ITACA is expected to shift from verification tools to active drivers of innovation, promoting synergistic solutions that jointly address indoor health, energy performance and climate adaptation. The systematic integration of radon control into the planning, design, operation and refurbishment of public buildings will therefore remain a key component of sustainable building policies, with direct benefits for occupant protection and long-term resilience of the public building stock.

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