

Review

Procedures for Indoor Radon Measurement in Recent Years: A Scoping Review

Silvia Tamborino , Paolo Maria Congedo *  and Cristina Baglivo 

Department of Engineering for Innovation, University of Salento, 73100 Lecce, Italy; silvia.tamborino@unisalento.it (S.T.); cristina.baglivo@unisalento.it (C.B.)

* Correspondence: paolo.congedo@unisalento.it

Abstract

Measuring indoor radon concentrations is essential for ensuring good air quality in buildings and protecting public health, but significant regulatory and methodological fragmentation still exists at the international level. This study analysed scientific articles published in the last five years, aiming to critically map the technical choices adopted in measuring radon in different indoor environments. The results show that regulatory fragmentation continues to generate inconsistent practices with regard to measurement protocols, sampling durations, devices used, and normative references used to interpret the results. In many cases, the protocols cannot be readily classified according to major technical standards as specific interpretation criteria are required, such as the sampling frequency and the overall duration of the strategy. These results highlight the importance of standardising measurement methods in order to improve the accuracy of exposure assessments and enable comparisons between studies.

Keywords: indoor radon measurement; indoor radon concentration; radon survey; radon legislation; measurement protocols



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1. Introduction

Radon gas is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC) [1] and is the second leading cause of lung cancer after smoking [2]. Despite the wide scientific agreement on the health risks associated with indoor radon exposure, the practical implementation of international recommendations on measurement methods, exposure limits, and mitigation strategies remains inconsistent. Existing guidelines and regulations are often applied differently across countries, leading to significant variations in threshold values, measurement methodologies, and intervention requirements. In some cases, the guidelines themselves lead to multiple interpretations, further limiting global harmonisation.

The World Health Organization (WHO), in its 2009 technical report, recommends a reference value of 100 Bq/m³, with the possibility of raising it to a maximum of 300 Bq/m³ in cases where it is technically difficult to further reduce the concentration [2]. However, these recommendations are not mandatory, and according to the WHO report (2021), many countries have not yet defined a National Reference Level (NRL) or have adopted thresholds above 300 Bq/m³ for workplaces (e.g., Turkey, Serbia, Lithuania, Georgia, China, Brazil, Belarus, Australia) [3].

In Europe, Directive 2013/59/Euratom requires Member States to provide national action plans to reduce the risk from exposure to radon, setting a maximum reference

level of 300 Bq/m³ for both homes and workplaces [4]. However, the implementation of the directive has generated a heterogeneous regulatory framework, as highlighted by a report by the Joint Research Centre (JRC) within the MetroRADON project [5], based on a literature review of national indoor radon surveys conducted in Europe. The adopted methodologies vary significantly, and many sources do not report key information on the design of the surveys, compromising the reliability and reproducibility of the results. The result is a complexity in developing a consistent map of the radon distribution across the continent [6]. Nevertheless, the authors acknowledge that, while methodological heterogeneity is an important issue, the main challenges in creating a continent-wide radon map derive primarily from the limited availability of data and the significant variability that can exist even between neighbouring buildings.

Unlike Europe, the United States adopts an “action level” concept instead of a binding reference level, set by the Environmental Protection Agency (USEPA) at 4 pCi/L (approx. 148 Bq/m³), but without imposing any regulatory requirements for existing buildings [7,8].

Furthermore, existing guidelines provide recommendations that are open to interpretation and lack uniformity. This is evident in the case of the sampling duration: the expression “long-term measurement” is variably defined. ISO 11665-1:2019 defines long-term measurements as over two months [9]; however, organisations such as the USEPA (through the Indoor Environments Association (IEA) and American National Standards Institute (ANSI) standards) [10], Health Canada [11] and the WHO [2] recommend durations of at least 90 days (preferably up to one year), while the Chinese National Standard GB/T 18883-2022 specifies that the exposure period of Solid-State Nuclear Track Detectors (SSNTDs) must not be less than three months, preferably during winter [12]. The indication of “more than three months” may encompass a wide range of exposure periods. Consequently, the common classification of “long-term measurements” includes widely varying durations (from 90 days to over a year), often without explicit methodological justification.

Although international frameworks provide reference levels and methodological guidance, regulatory heterogeneity and ambiguity complicate radon risk management, hindering the adoption of consistent prevention strategies across countries. Indeed, recent publications continue to apply heterogeneous methodologies, such as the measurement duration and the type of devices used, making international data incomparable. It should be noted that recent proposals, such as the Rational Method [8], offer a promising pathway toward addressing these inconsistencies. While still under development, such approaches could complement descriptive reviews by providing a conceptual basis for harmonisation and standardisation. Even though international standards exist, and efforts could be made to harmonise guidelines across countries, the main challenge is that these recommendations are not always rigorously applied or clearly reported in practice. This lack of rigorousness undermines repeatability, which is a fundamental requirement of experimental activity, and consequently compromises the comparability of results, even before taking into account regulatory fragmentation.

This review aims to examine how indoor radon has been measured in recent studies (2020–2024), focusing on direct measurements conducted for various purposes. These include, for example, mapping campaigns and surveys aimed at exploring correlations between indoor radon levels and various influencing factors. The objective is to analyse recent evidence by considering the following:

1. Indoor environments in different countries;
2. Measurement methodologies, sampling durations, and types of devices employed.

The central review questions are as follows: How do recent studies measure indoor radon in terms of methodological approaches, sampling durations, and types of devices? What consequences does this have for international comparability and risk management?

A scoping review approach was deemed appropriate to explore the range of existing methodologies, capture the diversity of practices, and highlight areas requiring greater harmonisation.

2. Materials and Methods

To study recent trends in indoor radon measurement, articles were retrieved from the Scopus Database using the following search string “(indoor AND radon AND monitoring) OR (indoor AND radon AND measurement) OR (indoor AND radon AND detection) OR (indoor AND radon AND concentration)”. The selection was limited to studies published between 2020 and 2024. The choice of this time frame was motivated by the increased attention on indoor air quality following the COVID-19 pandemic, evidenced by the growing number of publications on the topic. Although several studies published during this period may be based on measurements conducted before the pandemic, the year 2020 was chosen as a starting point because it represents a turning phase in both the scientific and societal awareness of indoor environments. Furthermore, the results have been filtered to select English-language papers published as final articles within the disciplinary areas of “Environmental Science”, “Physics and Astronomy”, “Engineering”, “Earth and Planetary Sciences”, and “Chemical Engineering”. Studies from the medical and chemical fields were not included, as they tend to focus on health effects or instrumentation optimisation rather than direct measurement.

After applying the predefined filters, the records were screened based on their titles and abstracts to assess their relevance. Potentially eligible articles were then evaluated by reading the full text to confirm their inclusion or exclusion. Excluded from the review were works dealing primarily with statistical or predictive analyses; studies relying on data from previous measurement campaigns conducted by third parties; investigations of radon exhalation from building materials; or measurements carried out in water, soil, and natural subsurface environments. Also omitted were articles dedicated to the performance evaluation of specific devices, contributions addressing humanistic aspects, and studies based on test chamber experiments. This review instead concentrates on methodologies adopted for measuring indoor radon concentrations in indoor environments, including dwellings, schools (ranging from kindergartens to universities), hospitals, and workplaces. No formal protocol was registered for this scoping review.

Figure 1 shows the PRISMA flowchart, which summarises the selection phases.

All included studies were organised into a database, which provides, for each analysed article, a set of structured information: general data (title, authors, university/institution of affiliation, year of publication, scientific journal), geographical details related to the location of the radon measurements, the type and duration of sampling (discrete, continuous, time-integrated, short- or long-term), and characteristics of the detectors used (passive/active, sampling and detection method, model name). The complete database is reported in the Supplementary Data. Based on this information, a systematic analysis of the data was conducted to identify the most frequently adopted sampling methods and the most used detector models in the international scientific literature.

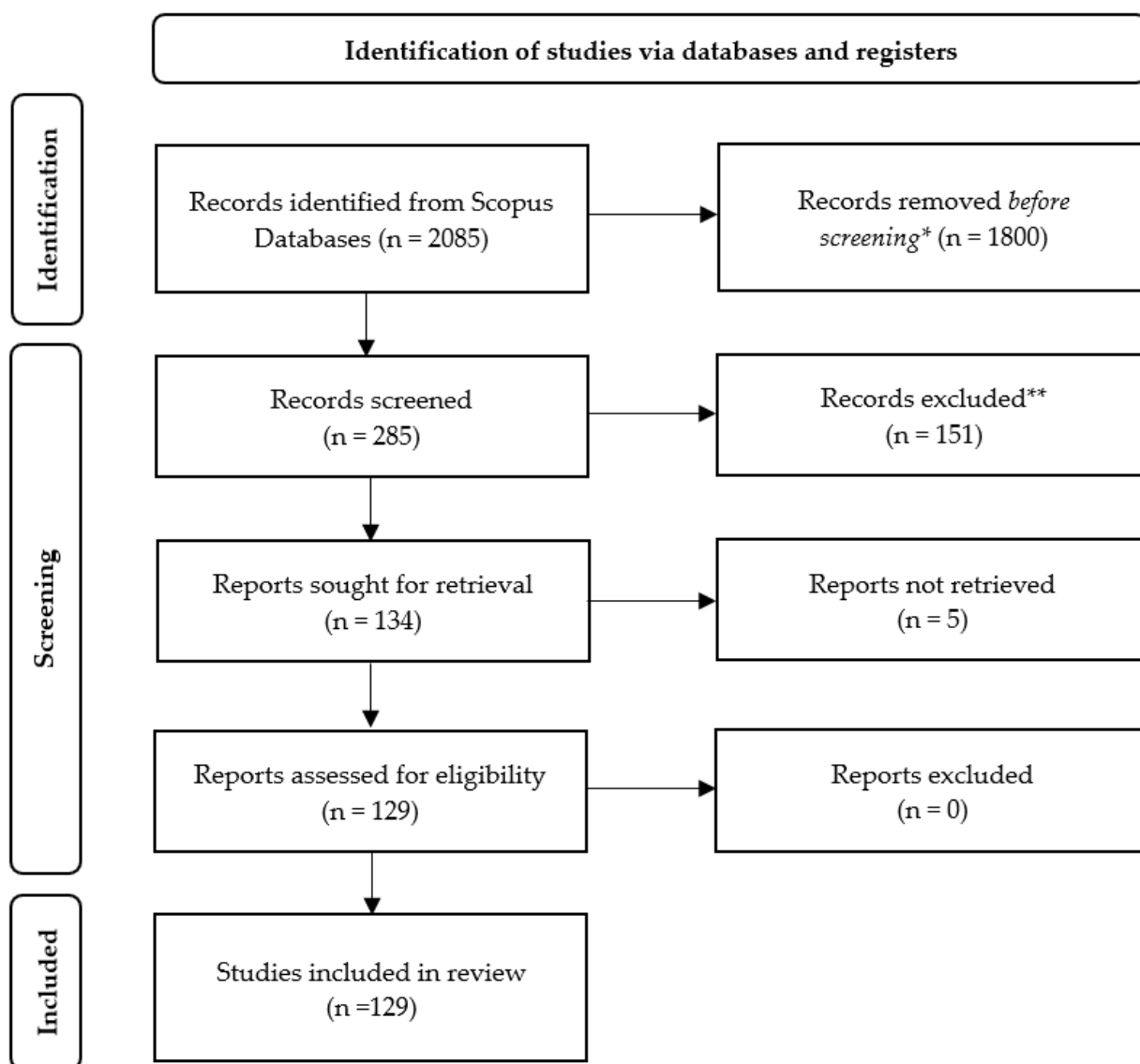


Figure 1. PRISMA flow diagram. * Applying the selection filters previously exposed. ** According to the exclusion criteria.

During the database compilation phase, some critical issues emerged regarding the classification of radon detectors. Although the commonly adopted distinction between “active” and “passive” detectors is based on the sampling method and the use of electrical power, this classification can be ambiguous. According to the EN ISO 11665-1 standard (which refers to the IEC 61577-1:2006, 3.2.22 definition) [9], active sampling requires the use of a mechanism, such as a pump, to convey air to the detector. However, electronic devices like the Corentium Home, generally considered active, use a passive diffusion chamber and, therefore, based solely on the sampling method, fall into the category of passive devices. The ANSI/AARST protocols confirm this ambiguity, classifying as passive even some electronic devices that do not automatically record a retrievable hourly time series (“continuous monitoring devices that are not set to or capable of automatically recording a retrievable time series of one-hour measurements”).

Another critical issue that emerged from the literature review concerns the temporal classification of radon measurements, that is the distinction between short-term and long-term measurements. In this study, the authors decided to deviate from the definition provided by ISO 11665-1:2019, adopting a duration greater than three months as the

threshold for long-term measurements. This criterion is consistent with practice and recommendations from international bodies such as the USEPA, Health Canada, the WHO, as well as the Chinese standard GB/T 18883-2022, which indicate a minimum duration of 90 days as a requirement to better represent seasonal variations in radon concentrations [3,10–12].

3. Results and Discussions

3.1. Selected Articles

The following section provides a brief description of the identified articles, categorising them according to their main topic.

3.1.1. Mapping

As for the selected articles, studies [13–19] conducted city survey investigations, with the aim, in the case of [15,18,19], of examining the health effects of radon exposure. In particular, Ref. [15] identified the number of buildings with average radon concentrations above the recommended threshold; Ref. [18] analysed the relationship between indoor and soil radon concentrations; and Ref. [19] investigated the various factors influencing indoor radon levels. The analysis of influencing factors was also conducted by study [14], while study [17] focused on the creation of a map of the indoor radon concentration (IRC).

In addition to [17], studies [20–24] also carried out IRC measurements to create concentration or risk maps. Among these, Refs. [20,22–24] focused on the health impact of radon exposure. Moreover, Ref. [20] explored the link between indoor radon and geological and geomorphological features, identifying priority areas for action; Ref. [24] investigated potential influencing factors; and Ref. [23] developed a new methodology for conducting nationwide surveys.

Along with study [23], studies [25–29] also conducted national surveys. Study [25] assessed the health impact on residents, while studies [26,27] focused on influencing factors. Study [27] also identified priority areas for intervention.

At the sub-national level, surveys were conducted by studies [30,31] (governorate level), [32] (provincial level), and [33,34] (regional level). All these studies considered health effects, except for [34], which focused exclusively on influencing factors.

3.1.2. Geological and Geomorphological Influence

In addition to study [20], Refs. [35–41] also analysed the relationship between the IRC and the geological or geomorphological characteristics of the site. Studies [35,38] identified high-risk areas, while study [38] further examined the variation in the IRC in relation to meteorological and environmental conditions. Study [36], on the other hand, also focused on the analysis of the radon diffusion process from the soil into buildings. Additional investigations were carried out in studies [40,41]: Ref. [40] examined the combined impact of ventilation systems and occupant activities, while study [41] also assessed the health effects associated with radon exposure.

3.1.3. Environmental and Meteorological Influence

The relationship between the IRC and environmental or meteorological parameters was analysed in studies [7,42–50]. Among these, Refs. [44,49,50] also evaluated health effects, with [50] specifically examining workplaces and [44] also analysing the relationship between radon and other pollutants.

The combined effects of radon and other pollutants were also studied in works [51,52]: the former examined the temporal variation in the radon concentration and influencing factors, while the latter focused on assessing the health impact of co-exposure.

3.1.4. Fluctuation

The temporal variation in the IRC was also analysed in studies [42,53–60]. Of these, [54,55,58,60] also evaluated health effects; in particular, studies [54,60] also explored the analysis of impact factors. Studies [53,59] also examined various influencing factors, and [53] also investigated the spatial distribution of indoor radon.

The spatial distribution of radon was also addressed in studies [61,62]: Ref. [61] carried out measurements in school environments, assessing risks for students and staff and analysing various influencing factors; Ref. [62] explored the relationship between indoor and outdoor radon, considering the factors affecting its variability.

3.1.5. School and Work Environments

School environments were also the focus of studies [42,61,63–74]. Many of these studies ([64,66–69,74]) focused on the assessment of health effects, while [64] also examined the relationship with the geological characteristics of the site. Like [61], studies [66–68] also investigated influencing factors. Studies [63,65] analysed the relationship between the IRC and building characteristics and construction materials, with [63] also evaluating the effect of ventilation. Study [42] focused instead on meteorological and environmental conditions, while [72] compared different measuring instruments and assessed the impact of occupant activities. Study [73] was limited to the analysis of potential influencing factors.

Workplace environments were the subject of numerous studies ([50,75–81]). In particular, in addition to [50], studies [75,77–79,81] mainly focused on health risk assessment. Specifically, Ref. [75] also explored the relationship between the IRC and geological characteristics; Ref. [78] analysed the relationship between indoor radon and concentrations in water, while [81] focused on the study of influencing factors. Study [80] assessed the impact of influencing factors, while [76] investigated the effects of building renovations on the IRC, also considering the influence of the materials used.

3.1.6. Building Influence

Similarly to study [76], studies [82,83] analysed the effects of building interventions and the relationship between the IRC and building characteristics, confirming the importance of materials and construction techniques. This topic was addressed more accurately in studies [84–95]. Some of these ([86–88]) also considered the geological component, with [88] also evaluating health effects and identifying at-risk buildings. The health impact is also central in studies [89,91–94], while [89,90,94] also analysed potential influencing factors. Study [92] also investigated the relationship between the IRC and soil radon concentration, which is the main topic of studies [96–98].

3.1.7. Health Risk

In addition to those mentioned above, [99–120] also measured the IRC to assess the health effects of radon exposure. In particular, study [101] examined whether the IRC exceeded the recommended values; studies [100,109,119] also evaluated potential influencing factors; study [120] evaluated the health radon exhalation rate; and study [106] evaluated residents' awareness about radon. These studies were conducted across diverse geographic regions, including Europe, Asia, and Africa, reflecting a global interest in the potential health effects of radon exposure.

3.1.8. Mitigation Techniques

Several studies have proposed indoor radon mitigation techniques. Studies [121–126] explored various strategies: study [121] focused on health effects; Ref. [125] investigated the

use of air purifiers; Ref. [126] examined passive soil pressurisation; and studies [123,124] analysed different ventilation systems.

3.1.9. Additional Influencing Factors

The impact of ventilation on the radon concentration was also discussed in study [127], while study [128] examined the relationship with radon presence in water. Studies [129,130] analysed the relationship with shale gas and biomass burning activity, respectively, while studies [131,132] investigated the influence of proximity to mines and mine tailings.

Studies [133,134] investigated the potential link between radon and seismic events, with study [134] developing a new predictive methodology.

Study [135] analysed the relationship between the indoor radon concentration (IRC) and building occupant activities, while study [136] investigated radon kinetics and influencing factors. Study [137] focused on identifying the contribution of radon sources.

3.1.10. New Measurement and Forecasting Approaches

Study [138] measured the IRC to compare different measurement methodologies. Finally, new measurement and forecasting approaches were developed in studies [7,139,140]. Studies [7,139] also analysed the factors that influence the IRC, with study [7] exploring the link with meteorological conditions in more detail. Study [140] focused on the health impacts of the IRC.

3.2. Data Synthesis

3.2.1. The Purpose of the Papers

The analysis of the examined articles made it possible to identify several macro-categories related to the research objectives followed by the authors. As previously observed, a study is rarely driven by a single motivation: multiple aims often coexist. Considering, for simplicity, only the most frequent primary objectives, it is possible to outline the main motivations behind these studies. Table 1 presents the main objectives identified in the reviewed articles, along with references to the specific studies that address each objective.

The predominant theme, found in 66 articles, concerns the health effects of exposure to indoor radon. Another common objective, identified in 32 articles, is the investigation of factors that may influence the radon concentration. However, in these studies, the analysis of such factors plays a secondary role, mostly limited to the simple observation of correlations that emerged during data collection, without constituting the core of the research.

In contrast, in another group of articles, the analysis of one (or more) specific influencing factor represents the primary objective of the study. In these cases, the investigations focused more systematically on one or more determinants of the radon concentration. In some studies, the initial focus was on a single factor, but over the course of the investigation, other elements were also considered, even if with less detail. Among the influencing factors, the most frequently analysed are building characteristics and construction materials (18 articles), geological or geomorphological characteristics of the site (14), meteorological conditions or environmental parameters (11), and ventilation systems (6).

Table 1. Main objectives identified in the reviewed articles, with corresponding references to the specific studies addressing each goal.

Subdivision of Articles According to Their Main Purpose										
	Radiation Health Impacts	Study in School Environments	Study in Working Environments	IRC and Geological/ Geomorphological Characteristics	IRC and Environmental Parameters/ Meteorological Conditions	IRC and Building Materials/ Characteristics	IRC and Ventilation System	Potential Impact Factor	Temporal Variation	Spatial Diffusion/ Distribution
n°	[15,18–20,22–25,30–33,41,44,49,50,52,54,55,58,60,61,64,66–69,74,75,77–79,81,88,89,91–94,99–121,130,133,134,140]	[42,61,63,65–74]	[50,75–81]	[20,35–41,45,64,75,86–88]	[7,38,42–50]	[48,63,65,76,82–95]	[40,63,95,123,124,127]	[7,14,19,24,26,27,34,51,53,54,59–62,66–68,73,80,81,89,90,94,100,106,109,119,126,131,136,137,139]	[48,51,53–60]	[36,46,53,61,62]
tot	66	13	8	14	11	18	6	32	10	5

As for the context of the measurements, 13 studies were conducted in school or university environments, and 8 were conducted in workplaces.

Finally, 10 articles examined the temporal variability of the radon concentration, from daily to seasonal scales, while 5 studies analysed the spatial distribution of the gas.

3.2.2. Radon Survey Design

The data analysis revealed significant heterogeneity in the measurement protocols adopted across the various studies. Table 2 shows the distribution of the analysed articles based on the sampling duration (long-term, short-term, or both) and the type of device used (passive, active, or both), highlighting the frequency with which each combination was employed in the analysed studies and the wide methodological variability found in the literature.

Table 2. The classification of the reviewed articles according to the sampling method (long-term LT, short-term ST, or both LT/ST) and the type of device used (active A, passive P, or both A/P).

	Subdivision of Articles According to Sampling Duration and Device Used								
	LT-P	LT-A	LT-A/P	ST-P	ST-A	ST-A/P	LT/ST-P	LT/ST-A	LT/ST-P/A
n°	[13,15,17,20–22,24–28,30–33,39,41,52,54,58,60–63,69–71,77,78,82–85,88–91,93–95,97–99,101,106–109,111–115,117–119,121,129,130,134,140]	[7,23,38,42–44,46,47,49–51,53,57,59,64,81,89,96,102,103,124,126,128,133,136–138]	[48,56]	[16,19,29,35,37,45,79,87,92,100,116,120,139]	[18,34,40,55,67,68,72,74,75,80,104,105,110,122,123,125,127,131]	[73,76,132,135]	[14]	[66]	[36,65,86]
tot	60	27	2	13	18	4	1	1	3

In several cases, a single sampling method or time window was not employed. For example, in [14] a single type of device was used for measurements conducted over different time intervals, while others used multiple devices while keeping the type of measurement (long-term or short-term) constant, varying the specific sampling duration ([48,56,73,76]) or maintaining it ([132,135]). In other cases, both active and passive devices were employed, conducting both short-term and long-term measurements [36,65,66,86].

It should be noted, however, that in most cases these choices are justified: often the reason is the intention to use passive devices for long-term monitoring, alongside active devices used as confirmation or to obtain precise measurements at specific times, depending on the purpose of the survey.

In general terms, a tendency can be observed toward the use of passive devices for long-term measurements and active devices for short-term ones. This trend, observed across the different geographical and application contexts examined, reflects a methodological convergence toward approaches that ensure greater temporal representativeness and operational simplicity.

Both sampling methods, however, have limitations. Short-term measurements, while allowing for the rapid acquisition of high-precision data, do not guarantee an accurate representation of the annual average radon concentration due to daily and seasonal fluctuations. Therefore, short-term measurements are more suitable for assessing the effectiveness of mitigation interventions or for studying concentration variations in relation to ventilation conditions or occupant activities.

Long-term measurements, on the other hand, while offering a more representative average value of annual conditions, have the limitation of integrating all radon concentration variations during the sampling period, without allowing the observation of short-term fluctuations. This method is therefore ideal for verifying compliance with the exposure limits established by current regulations.

For both short- and long-term measurements, sampling is generally recommended during the winter period. This follows the pessimistic principle of radiological protection, which considers the worst-case scenario of the highest radon concentrations.

3.2.3. Relationship Between Study Purpose and Measurement Methodology

Table 3 summarises the relationship between the primary research purposes (Table 1) and the corresponding measurement protocols in terms of the sampling duration and device type (Table 2). Only the articles listed in Table 1 associated with the most frequent purposes were considered.

Table 3. The distribution of reviewed articles according to the study purpose and measurement approach. The classification includes only the articles reported in Table 1, based on the most frequent purposes identified.

Article Counts by Purpose Category and Measurement Approach									
	LT-P	LT-A	LT-A/P	ST-P	ST-A	ST-A/P	LT/ST-P	LT/ST-A	LT/ST-P/A
Radiation health impacts	41	9		6	9			1	
Study in school environments	5	1			4	1		1	1
Study in working environments	2	2		1	2	1			
IRC and geological/geomorphological characteristics	4	2		4	2				2
IRC and environmental parameters/meteorological conditions		9	1	1					
IRC and building materials/characteristics	12		1	2		1			2
IRC and ventilation system	2	1			3				
Potential impact factor	13	8		3	5	1	1	1	
Temporal variation	3	4	2		1				
Spatial diffusion/distribution	2	2							1

Correlating the data indicates that a long-term measurement approach using passive devices is predominantly adopted for the assessment of health effects. In school environments, both long- and short-term approaches are employed, although the most frequently observed combination is “long-term/passive device” and “short-term/active device”. To investigate the correlation between indoor radon and environmental parameters or meteorological conditions, long-term assessments using active devices are favoured to ensure accurate measurements and analyse variations over extended periods. For evaluating potential impact factors, long-term measurements using passive and active devices are favoured. Generally, long-term measurements are favoured for studying spatial and temporal variations. For other categories, no specific preference is evident, and the different methods are applied roughly equally.

3.2.4. Sampling Duration

The sampling duration represents a crucial element in the measurement of the radon activity concentration in indoor environments. However, from the analysis of the reviewed literature, a scarcity of clarity in the description of this methodological aspect frequently

emerges, despite it being one of the fundamental elements in the presentation of the measurement protocol. Moreover, in several cases, the adopted protocols did not clearly fall into any of the standard categories defined by major guidelines, as the measurements were neither continuous over the entire investigation period, time-integrated, nor spot measurements. For example, in [96] sampling was carried out for about 2 min per day for six months; in [102] it was carried out for one hour per day over the course of a year; in [103] sampling was conducted for one hour per month, again for a year; in [128] it was conducted for two weeks per year, repeated over five years; in [38] sampling was carried out for one hour per day for six months; and in [50] it was carried out for 24 h, five times a month for four months.

During the classification phase, the challenge was to determine whether such protocols could be considered long-term or, rather, repeated short-term measurements over time. Since the main guidelines do not specify a classification for hybrid protocols with short but repeated measurements, it was necessary to introduce an operational criterion based on the sampling frequency and total duration of the survey, in order to ensure a consistent and meaningful classification of the available data.

In the case of [38,96,102], despite the short duration of each session (from a few minutes to an hour), the high frequency (daily measurements) and the long overall duration of the protocol led us to consider these strategies as long-term measurements, as they could potentially provide a reliable representation of the temporal trend of the radon concentration. However, it should be noted that, although these daily short measurements are considered long-term according to our operational criteria, they inherently carry a higher degree of uncertainty than continuous measurements. Conversely, in studies such as [50,103,128,132], the low sampling frequency (ranging from once a month to two weeks per year) was considered insufficient to meaningfully represent the annual variability of the radon concentration. Consequently, these approaches were classified as repeated short-term measurements over time and not as true long-term protocols.

In cases of annual or multiyear monitoring, such as in [56,60,108], the measuring devices were regularly replaced every 3–6 months with the same type of detector, so as to ensure the continuity of the measurement method. However, in order to highlight the scope and objectives of long-term monitoring programmes, the overall duration of the campaign was considered, rather than that of the individual devices used. In other cases, such as in [27,86], since these were extensive surveys conducted on large samples of buildings, the campaigns extended over several years, but the measurement duration in each building ranged between 3 and 6 months. In these cases, the actual measurement duration per building was considered, as the overall temporal extension did not reflect continuous monitoring on a single residential unit.

The analysis of the duration of long-term measurements, reported in Figure 2, highlights high variability, with campaigns ranging from a minimum of three months up to more than two years.

Measurements lasting less than one year constitute 68% of the total. In 38% of the studies the devices were used for three months, thus representing the minimum time to classify the measurement as long term.

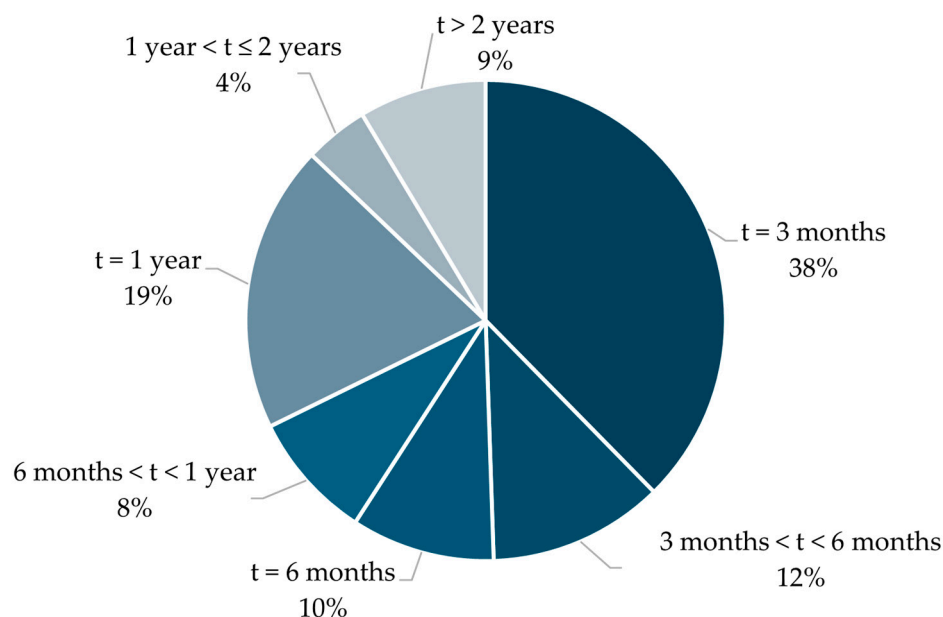


Figure 2. Number of long-term radon measurements conducted across different time intervals (t).

Guidelines generally recommend a minimum duration of three months, preferably during the winter season when radon concentrations are higher on average. Although it is not always simple to determine whether a measurement falls entirely within the winter period, as it may overlap with autumn or spring in some cases, it was possible to establish that 61.5% of long-term analyses were conducted during the winter season. This percentage includes studies performed throughout the year (thus covering the winter months), studies that explicitly report winter season coverage, studies conducted specifically during the winter months, and studies that start in autumn and extend into winter. For studies conducted in the Northern Hemisphere, winter was defined as December–February, and for studies conducted in the Southern Hemisphere, the corresponding winter months (June–August) were used. In the remaining cases, either the months of measurement were not specified or monitoring was limited to the spring and summer.

However, this marked heterogeneity in sampling times leads to measurements lasting longer than three months but with widely varying durations. This creates a sense of disorder and the impression that a specific protocol is not being followed. Furthermore, the choice of measurement duration is often not justified, leaving the reader feeling uncertain. Such variability in sampling periods makes the direct comparison of results between studies conducted in different geographical contexts complex, especially when the objective is to analyse the seasonal trend of radon concentrations or identify possible correlations with climatic, building, or behavioural factors at an international level.

Regarding short-term measurements, Figure 3 illustrates the percentage distribution of durations adopted for short-term radon measurements in the analysed studies.

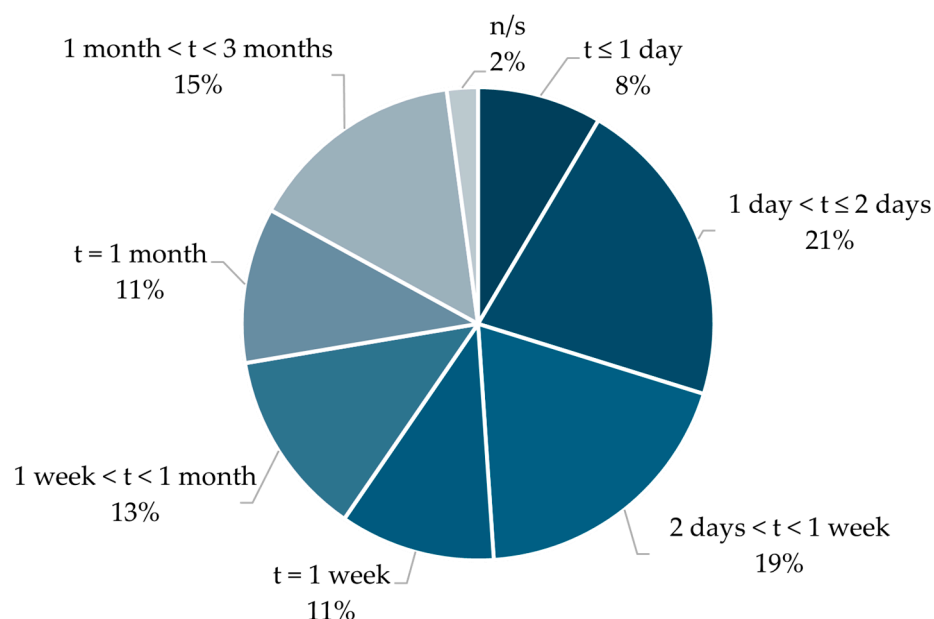


Figure 3. Number of short-term radon measurements conducted across different time intervals (t). Note: n/s = not specified.

Measurements lasting less than one week (almost 50% when combining the first three categories) highlight a tendency to prefer quick approaches, which are often easier to manage logistically but may be less representative of the time variation of radon. The significant presence of durations close to the lower limit of long-term periods (up to 3 months) also suggests that, in some cases, short measurements are extended to improve the reliability of the results, while still being classified as short-term.

3.2.5. Type of Device

The choice between active and passive devices for indoor radon measurement is often influenced by economic, logistical, and operational considerations. Passive devices, especially SSNTDs based on CR-39, are particularly suitable for large-scale monitoring campaigns (at the municipal, regional, or national level). As highlighted by the International Atomic Energy Agency (IAEA) in the document “National and Regional Surveys of Radon Concentration in Dwellings: Review of Methodology and Measurement Techniques”, these devices meet key requirements for such surveys: low unit costs, compact sizes, and the ability to perform sampling for durations between 3 and 12 months [141].

Another operational advantage of passive devices is that they do not require electrical power and must be kept in a fixed position for the entire sampling period. These features make them easier to use in citizen science programmes and measurement campaigns involving the direct participation of residents, through the distribution of measurement kits for home use. In contrast, active devices, while offering the advantage of real-time measurements through integrated displays and electronic processing systems, are generally intended for professional or research use. They require the presence of qualified personnel for management and are mainly used in short-term surveys that demand a high resolution.

The data collected in this study show a clear predominance of passive devices, which can be divided into three categories: SSNTDs, activated charcoal, and electret. Among these, SSNTDs were used 74 times, accounting for 87.1% of the total. Next are detectors using activated charcoal for sampling, used eight times (9.4%), and, finally, electret-based detectors were used only three times (3.5%), as shown in Figure 4.

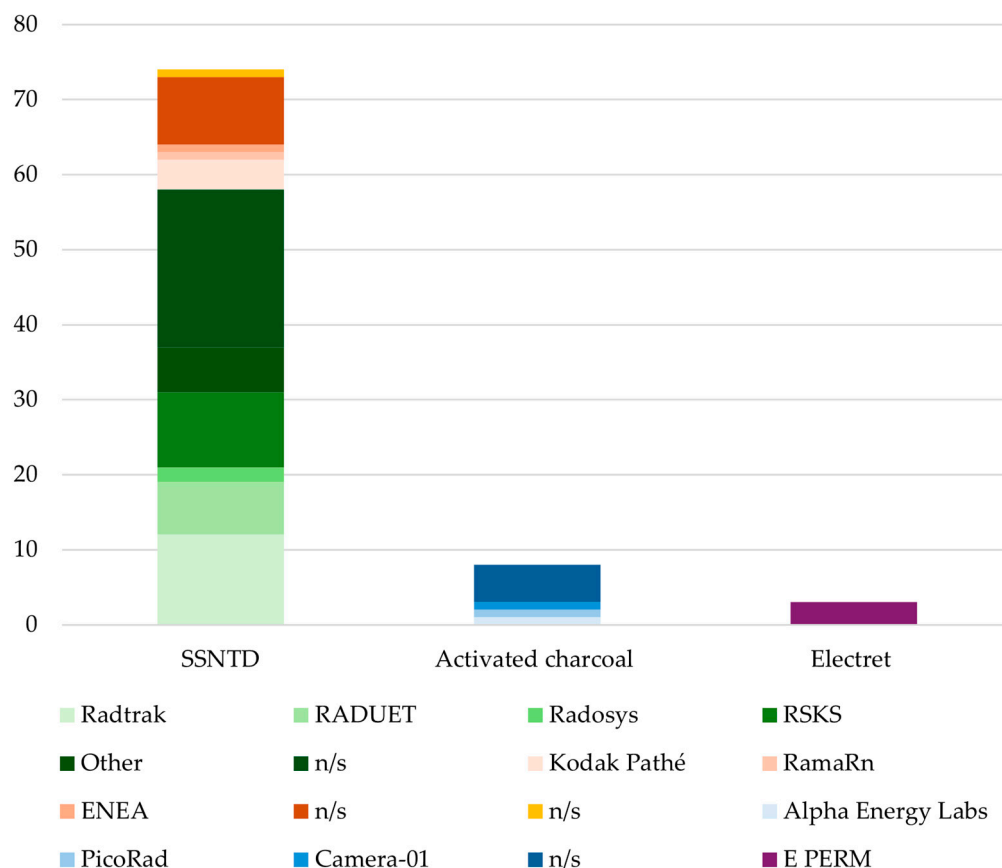


Figure 4. Distribution of passive radon detectors across the three main categories: SSNTD, activated charcoal, and electret. Note: n/s = not specified.

Within the SSNTDs, CR-39 (in green) is the most frequently used material with a frequency of 79%, while LR-115 (in orange) appears in 20% cases. In only 1% of the studies it was not possible to determine the type of detector used due to a lack of specific information (in grey). However, in most cases, only the type of plastic material is reported (e.g., CR-39), without specifying the manufacturer or the exact model of the detector. Regarding CR-39, the green colour gradation shows the distribution of models used, as indicated in the various articles examined. Moreover, it should be noted that in a significant portion of cases (36%), the manufacturer was not specified. Among the most frequently mentioned models are Radtrak® (Radonova, Inc., Lombard, IL, USA), used in 21% of cases, and RSKS by Radosys Ltd. (Budapest, Hungary), with a frequency of 17%. In a further 4% of the studies, the brand Radosys was mentioned without specifying the exact model. This data reflects a certain variability in device selection but also a lack of detail in experimental descriptions, which can represent a limitation in terms of the reproducibility and comparability of results.

Active devices can also be classified into four main technology categories, according to ISO 11665-1:2019 [8]: ionisation chambers, solid-state sensors, scintillation detectors, and liquid scintillation devices. Among these, as highlighted in Figure 5, the most used type is the solid-state sensor, used in 45 cases, which is equal to 64.7% of the total identified active devices. These are followed by ionisation chambers, used in 25% of cases, and scintillation detectors, with a frequency of 10.3%.

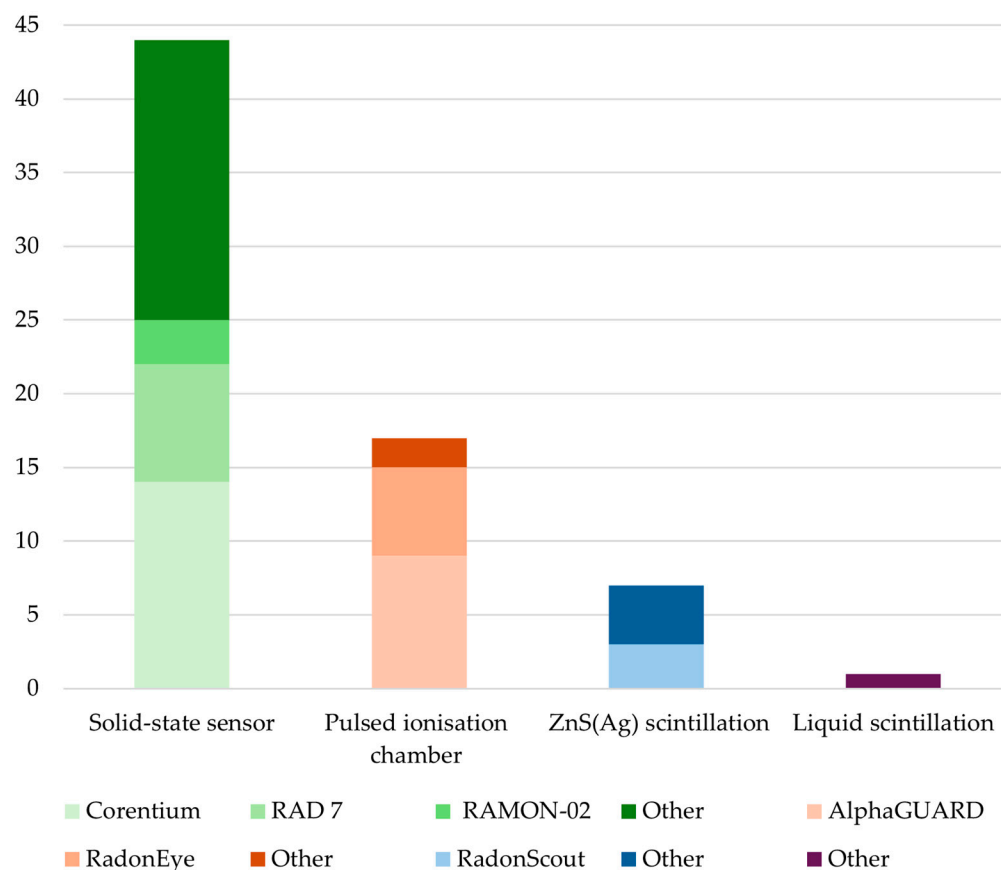


Figure 5. Distribution of active radon detectors used across the four main categories: solid-state sensor, ZnS(Ag) scintillation, liquid scintillation, and pulsed ionisation chamber.

More specifically, for solid-state sensors, the most represented devices belong to the Corentium[®] family (including the Home, Plus, and Pro models), used in 32% of cases. Next is RAD7 (DurrIDGE Company Inc., Billerica, MA, USA), with 18%, and RAMON-02, with a frequency of 7%. The remaining devices, grouped under the “other” category (43%), include a variety of instruments mentioned in only one or two studies and are therefore not individually reported, as they are not significant for this comparative analysis.

Regarding ionisation chamber devices, the most frequently used model is AlphaGUARD[®] (Bertin Technologies SAS, Montigny-le-Bretonneux, France), with various versions available on the market, used in 53% of the studies employing this technology. Next is the RadonEye[®] device (RadonFTLab, Ansan-si, Korea), with a usage rate of 35%. Again, the remaining less frequently used instruments (each cited only once) have been grouped into the “other” category (12%). Finally, for scintillation detectors based on ZnS(Ag), there is a prevalence of the RadonScout[®] device (SARAD GmbH, Dresden, Germany), which appears in 43% of cases. The remaining 57% consists of other models, each with a marginal presence, also grouped under the “other” label.

This overview confirms a marked preference by the scientific community for solid-state sensors in the active monitoring of IRCs, likely due to their greater portability, ease of use, and continuous data acquisition capability and the availability of reliable commercial devices at low costs.

3.2.6. Detector Grade

One particularly important aspect that emerged from the analysis is the classification of devices used to measure radon concentrations. In the reviewed articles and technical data sheets for each device, these are often categorised as consumer-, professional-, or research-

grade. However, there is currently no universally recognised international definition. The distinction between these classes is generally based on economic criteria (for example, purchase price) and technical parameters, such as the device sensitivity, measurement range, operational autonomy, and time resolution. Consumer detectors offer lower performance levels, while professional- and research-grade detectors perform more effectively. However, this classification is not always clear-cut: professional sensors perform similarly to consumer sensors at low radon concentrations and match research-grade sensors at high concentrations [142], making precise classification difficult. Consumer-grade detectors are detectors designed for home use. In the case of electronic devices, although they do not have the accuracy of professional monitors, they allow homeowners to obtain data in near real time [143].

It should be noted that in this review the device grade classification was not based on an independent criterion, but rather the category assigned to each device (consumer, professional, or research) corresponds to that explicitly indicated in the reviewed articles or, where applicable, in the manufacturer's technical documentation. The classification reported in the respective articles was adopted after verifying consistency with the manufacturer's technical documentation. In several cases, the categorization reported in the reviewed articles does not match the classification declared by the manufacturer, highlighting a certain interpretative heterogeneity within the scientific literature. In case of discrepancies, priority was given to the manufacturer's official classification, which was considered more reliable.

A specific issue has emerged regarding SSNTDs. Although these devices are among the most affordable on the market, their application requires post-exposure laboratory processing for track analysis, which makes them less practical for individual citizens to use. Furthermore, some manufacturers offer an integrated reading and analysis service, while others provide only the device, leaving the researcher responsible for the analytical phase. In this study, SSNTDs are classified as professional-grade devices, reflecting the practical requirement for laboratory processing and specialised equipment, despite their low cost. Other passive devices, such as electret and charcoal canisters, have been classified as professional only when explicitly indicated by the manufacturer (two cases). The remaining passive devices are left unclassified, as no official classification was provided.

Considering SSNTDs as professional devices, they are the most frequent, followed by consumer devices and then research devices, while in 10 cases the classification level was not specified. It has also been observed that a limited number of studies used multiple devices belonging to different categories, usually with the aim of making direct comparisons between instruments or to pair a low-cost SSNTD with an active monitor of a professional or research level, thus obtaining complementary measurements and a broader temporal characterisation of the environment under investigation.

3.2.7. Reference Value

Once the radon concentration has been measured and the different health risk indices estimated, it is important to critically analyse the results obtained. The first step is to ensure that these values are below the recommended limits or those imposed by the national regulations in force in the country where the study was conducted. If this is not the case, actions must be taken on the building under study to reduce the value.

Table 4 provides a detailed overview of scientific articles that have compared their IRC results with reference limits set by various international and national institutions.

Table 4. Classification of the reviewed articles according to threshold value as reference points in their research.

Subdivision of Articles According to Threshold Values Considered							
	WHO	ICRP	IAEA	UNSCEAR	Directive 2013/59/EURATOM	USEPA	National Reference Level
n°	[15,17,22,24,25,31–33,36–39,44,45,49,51,54,55,64,65,67,71–74,76,77,80,81,83,85,88,90–92,94,98,100,101,105–108,110,111,114,121,127,130,131,139]	[22,24,32,33,43,49,58,61,67,77,91,92,94,97,98,100,107,108,111,113–116,118,130]	[31,62,100]	[39,98–100,103,107,109,115,119]	[15,23,26,34–36,38,43,55,57,60,63–65,68,70,76,77,87,88,101,102,104,115,132,134,139]	[16,24,30,31,33,44,55,73,75,77,94,103,114,135]	[18,23,26–28,32,35,40,41,46,57,60,64,65,69–72,74,78,79,82,83,86,88,100,101,103,109,112,119,120,122–124,126,127,129,134,139]
tot	51	25	3	9	27	14	39

The WHO and the Directive 2013/59/EURATOM are the two sources most frequently adopted as normative references. This highlights the global influence of their recommendations. The WHO is cited in 51 articles, reflecting the strong impact of its guidelines, particularly the recommended threshold of 100 Bq/m³ (or 300 Bq/m³ as an upper limit). The International Commission on Radiological Protection (ICRP) is another authoritative source, cited in 25 articles. Other international institutions, such as the IAEA and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), are also used as references, but, on the other hand, the latter is often cited for the global average IRC, although some articles report expressions such as the “allowable limit” or “recommended limit” in the text, even though the UNSCEAR does not propose threshold values.

The category “National Reference Level” includes 39 citations, attributable to studies that referred to reference levels established by their respective countries. This highlights how some studies prefer to apply national or regional thresholds, likely for reasons of regulatory compliance or local practical application. However, when a single study compares its results with multiple threshold values that differ from one another, it raises the question of how to ultimately determine whether the measurements identify a priority area. For example, a site could be below the limits set by the EURATOM Directive but above the WHO recommended values, creating ambiguity in prioritising actions or interventions.

4. Conclusions

The review of articles measuring indoor radon concentrations for various purposes, primarily to evaluate health impacts on occupants, revealed significant differences in indoor radon measurement methodologies, such as sampling durations, device selection, and regulatory reference limits. Although international health authorities recommend minimum measurement periods of at least three months, the flexibility of this recommendation results in a wide range of study durations. This review highlighted a considerable variability in the correspondence between the measurement duration and the device type. Passive detectors, particularly CR-39 SSNTDs, are widely used for economic and logistical reasons. However, in the literature analysed, the models used are often not declared and uniquely identifiable. Among active devices, solid-state sensors are prevalent, but the diversity of models and the absence of a universally accepted classification of instruments as consumer, professional, or research grade represents a critical issue that limits comparability across studies. Additionally, varying regulatory thresholds hinder the consistent comparison of results; however, WHO guidelines and Directive 2013/59/EURATOM remain the most widely adopted references by far.

These discrepancies underline the need for a coordinated international effort to harmonise indoor radon measurement methodologies, to improve data quality and comparability, to support effective mitigation policies, and to provide a solid and shared regulatory framework.

While this review is confined to articles published in English between 2020 and 2024, this focus enabled us to examine the most recent studies and furnish a current overview of indoor radon measurement practices. It should also be noted that, although studies from the medical and chemical fields were excluded to maintain a focus on direct measurement practices, it is not possible to completely rule out the presence of some methodological insights in these areas. Future research could consider a longer timeframe to explore potential changes in measurement methods over time, as well as a broader inclusion of studies from different fields to capture additional methodological insights.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/buildings15203725/s1>: Table S1: Database of included studies: general information, measurement location, sampling details and detector characteristics.

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Abbreviations

The following abbreviations are used in this manuscript:

ANSI	American National Standards Institute
IEA	Indoor Environments Association
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
IRC	Indoor Radon Concentration
JRC	Joint Research Centre
NRL	National Reference Level
SSNTD	Solid-State Nuclear Track Detector
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

References

1. IARC Monographs on the Identification of Carcinogenic Hazards to Humans. Available online: <https://monographs.iarc.who.int/> (accessed on 10 May 2025).
2. WHO. *Handbook on Indoor Radon: A Public Health Perspective*; World Health Organization: Geneva, Switzerland, 2009.

3. WHO. National Radon Reference Levels, Data by Country. Available online: <https://apps.who.int/gho/data/view.main.RADON03v> (accessed on 15 May 2025).
4. EU-BSS. Council directive 2013/59/Euratom, laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation and repealing directives 89/618, 90/641, 96/29, 97/43 and 2003/122/Euratom. *Off. J. Eur. Union* **2014**, L13. Available online: <http://data.europa.eu/eli/dir/2013/59/oj> (accessed on 12 October 2025).
5. Pantelić, G.; Čeliković, I.; Živanović, M.; Vukanac, I.; Nikolić, J.K.; Cinelli, G.; Gruber, V. *Literature Review of Indoor Radon Surveys in Europe*; Publications Office of the European Union: Luxembourg, 2018; p. JRC114370. [[CrossRef](#)]
6. Pantelić, G.; Čeliković, I.; Živanović, M.; Vukanac, I.; Nikolić, J.K.; Cinelli, G.; Gruber, V. Qualitative Overview of Indoor Radon Surveys in Europe. *J. Environ. Radioact.* **2019**, *204*, 163–174. [[CrossRef](#)]
7. Tsapalov, A.; Kovler, K. Studying temporal variations of indoor radon as a vital step towards rational and harmonized international regulation. *Environ. Chall.* **2021**, *4*, 100204. [[CrossRef](#)]
8. Tsapalov, A.; Kovler, K.; Kiselev, S.; Yarmoshenko, I.; Bobkier, R.; Miklyaev, P. IAEA Safety Guides vs. Actual Challenges for Design and Conduct of Indoor Radon Surveys. *Atmosphere* **2025**, *16*, 253. [[CrossRef](#)]
9. *ISO 11665-1:2019; Measurement of Radioactivity in the Environment—Air: Radon-222—Part 1: Origins of Radon and Its Short-lived Decay Products and Associated Measurement Methods*. International Organization for Standardization: Geneva, Switzerland, 2019.
10. ANSI/AARST MAH, Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes. Available online: www.radonstandards.us (accessed on 18 May 2025).
11. Canada.ca, Guide for Radon Measurements in Residential Dwellings (Homes). Available online: <https://www.canada.ca/en/health-canada/services/publications/health-risks-safety/guide-radon-measurements-residential-dwellings.html> (accessed on 15 May 2025).
12. *GB/T 18883-2022; Indoor Air Quality Standard*. Standardization Administration of China (SAC): Beijing, China, 2022.
13. Smetanová, I.; Csicsay, K.; Marko, F. Indoor Radon Monitoring in Zázrivá. *Contrib. Geophys. Geod.* **2024**, *54*, 213–224. [[CrossRef](#)]
14. Hasan, M.M.; Janik, M.; Pervin, S.; Iimoto, T. Preliminary Population Exposure to Indoor Radon and Thoron in Dhaka City, Bangladesh. *Atmosphere* **2023**, *14*, 1067. [[CrossRef](#)]
15. Hansen, V.; Sabo, A.; Korn, J.; MacLean, D.; Rigét, F.F.; Clausen, D.S.; Cubley, J. Indoor Radon Survey in Whitehorse, Canada, and Dose Assessment. *J. Radiol. Prot.* **2023**, *43*, 011515. [[CrossRef](#)]
16. Elewee, A.A.; Aswood, M.S. Estimation of Indoor Radon Concentration in Some Houses in Al-Shatra District, Dhi-Qar Governorate, Iraq. *Nat. Environ. Pollut. Technol.* **2022**, *21*, 1747–1752. [[CrossRef](#)]
17. Loffredo, F.; Opoku-Ntim, I.; Kitson-Mills, D.; Quarto, M. Gini Method Application: Indoor Radon Survey in Kpong, Ghana. *Atmosphere* **2022**, *13*, 1179. [[CrossRef](#)]
18. Manić, V.; Manić, G.; Stojanović, M.; Radojković, B.; Krstic, D.; Nikezić, D. A Preliminary Survey of Natural Radionuclides in Soil and Indoor Radon in the Town of Niš, Serbia. *J. Radioanal. Nucl. Chem.* **2021**, *329*, 671–677. [[CrossRef](#)]
19. Bem, H.; Janiak, S.; Przybył, B. Survey of indoor radon (Rn-222) entry and concentrations in different types of building in Kalisz, Poland. *J. Radioanal. Nucl. Chem.* **2020**, *326*, 1299–1306. [[CrossRef](#)]
20. Briones, C.; Jubera, J.; Alonso, H.; Olaiz, J.; Santana, J.T.; Rodríguez-Brito, N.; Arriola-Velásquez, A.C.; Miquel, N.; Tejera, A.; Martel, P.; et al. Indoor Radon Risk Mapping of the Canary Islands Using a Methodology for Volcanic Islands Combining Geological Information and Terrestrial Gamma Radiation Data. *Sci. Total Environ.* **2024**, *922*, 171212. [[CrossRef](#)] [[PubMed](#)]
21. Briones, C.; Jubera, J.; Alonso, H.; Olaiz, J.; Santana, J.T.; Rodríguez-Brito, N.; Arriola-Velásquez, A.C.; Miquel, N.; Tejera Cruz, A.; Martel, P. Multiparametric Analysis for the Determination of Radon Potential Areas in Buildings on Different Soils of Volcanic Origin. *Sci. Total Environ.* **2023**, *885*, 163761. [[CrossRef](#)] [[PubMed](#)]
22. Mbida Mbembe, S.; Akamba Mbembe, B.; Manga, A.; Ele Abiama, P.; Saidou; Ondo Meye, P.; Owono Ateba, P.; Ben-Bolie, G.H. Indoor Radon, External Dose Rate and Assessment of Lung Cancer Risk in Dwellings: The Case of Ebolowa Town, Southern Cameroon. *Intern. J. Environ. Anal. Chem.* **2023**, *103*, 5957–5973. [[CrossRef](#)]
23. Corețchi, L.; Ene, A.; Ababii, A. Control of the Health Risk of Radon Exposure in the Republic of Moldova. *Atmosphere* **2021**, *12*, 1302. [[CrossRef](#)]
24. Adelikhah, M.; Shahrokhi, A.; Imani, M.; Chałupnik, S.; Kovács, T. Radiological Assessment of Indoor Radon and Thoron Concentrations and Indoor Radon Map of Dwellings in Mashhad, Iran. *Int. J. Environ. Res. Public Health* **2021**, *18*, 141. [[CrossRef](#)]
25. Miao, X.; Su, Y.; Hou, C.; Song, Y.; Ding, B.; Cui, H.; Wu, Y.; Sun, Q. Indoor radon survey in 31 provincial capital cities and estimation of lung cancer risk in urban areas of China. *Biomed. Environ. Sci.* **2024**, *37*, 1294–1302. [[CrossRef](#)]
26. Reste, J.; Rīmere, N.; Romans, A.; Martinsone, Ž.; Mārtiņšone, I.; Vanadzīņš, I.; Pavlovskā, I. Assessment of Indoor Radon Gas Concentration in Latvian Households. *Atmosphere* **2024**, *15*, 611. [[CrossRef](#)]
27. Gruber, V.; Baumann, S.; Wurm, G.; Ringer, W.; Alber, O. The New Austrian Indoor Radon Survey (ÖNRAP 2, 2013–2019): Design, Implementation, Results. *J. Environ. Radioact.* **2021**, *233*, 106618. [[CrossRef](#)]

28. Savković, M.E.; Udovičić, V.; Maletić, D.; Pantelić, G.; Ujčić, P.; Čeliković, I.; Forkapić, S.; Marković, V.; Arsić, V.; Ilić, J.; et al. Results of the First National Indoor Radon Survey Performed in Serbia. *J. Radiol. Prot.* **2020**, *40*, N22–N30. [[CrossRef](#)]
29. Tsapalov, A.; Kovler, K.; Shpak, M.; Shafir, E.; Golumbic, Y.; Peri, A.; Ben-Zvi, D.; Baram-Tsabari, A.; Maslov, T.; Schrire, O. Involving Schoolchildren in Radon Surveys by Means of the “RadonTest” Online System. *J. Environ. Radioact.* **2020**, *217*, 106215. [[CrossRef](#)]
30. Aswood, M.S.; Alhous, S.F.; Abdulridha, S.A. Life Time Cancer Risk Evaluation Due to Inhalation of Radon Gas in Dwellings of Al-Diwaniyah Governorate, Iraq. *Nat. Environ. Pollut. Technol.* **2022**, *21*, 331–337. [[CrossRef](#)]
31. Al-Shboul, K.F.; Al-Ajlony, A.-M.B.A.; Al-Malkawi, G.H.; Yaseen, Q.M.B. Radiation Hazards and Lifetime Risk Assessment Related to Indoor and Outdoor Air Inhalation Using a Passive Detection Technique. *Air Qual. Atmos. Health* **2021**, *14*, 1877–1887. [[CrossRef](#)]
32. Yalim, H.A.; Gümüş, A.; Açıllı, D.; Ünal, R.; Yıldız, A. Indoor Radon Activity Concentrations and Effective Dose Rates at Houses in the Afyonkarahisar Province of Turkey. *Arab. J. Geosci.* **2020**, *13*, 91. [[CrossRef](#)]
33. Akuo-ko, E.O.; Adelikhah, M.; Amponsem, E.; Csordás, A.; Kovács, T. Investigations of Indoor Radon Levels and Its Mapping in the Greater Accra Region, Ghana. *J. Radioanal. Nucl. Chem.* **2024**, *333*, 2975–2986. [[CrossRef](#)]
34. Ptiček Siročić, A.; Stanko, D.; Sakač, N.; Dogančić, D.; Trojko, T. Short-Term Measurement of Indoor Radon Concentration in Northern Croatia. *Appl. Sci.* **2020**, *10*, 2341. [[CrossRef](#)]
35. Zeybek, M.; Alkan, T. Geological and Geostatistical Modeling of Indoor Radon Concentration in Buildings of İzmir Province (Western Turkey). *J. Environ. Radioact.* **2024**, *280*, 107571. [[CrossRef](#)] [[PubMed](#)]
36. Voltattorni, N.; Giammanco, S.; Galli, G.; Gasparini, A.; Neri, M. Indoor Radon Monitoring and Associated Diffuse Radon Emissions in the Flanks of Mt. Etna (Italy). *Atmosphere* **2024**, *15*, 1359. [[CrossRef](#)]
37. Le Roux, R.; Bezuidenhout, J. Assessment of Radon and Naturally Occurring Radionuclides in the Vredefort Meteorite Crater in South Africa. *Atmosphere* **2023**, *14*, 1826. [[CrossRef](#)]
38. Spasić, D.; Gulan, L. High Indoor Radon Case Study: Influence of Meteorological Parameters and Indication of Radon Prone Area. *Atmosphere* **2022**, *13*, 2120. [[CrossRef](#)]
39. Otoo, F.; Darko, E.O.; Garavaglia, M. Correlation Analysis of Natural Radionuclides, Radon Exposure, Soil Particles, and Moisture from Quarry Towns in Greater Accra Region, Ghana. *Water Air Soil Pollut.* **2022**, *233*, 338. [[CrossRef](#)]
40. Curado, A.; Lopes, S.I.; Antão, A. On the relation of geology, natural ventilation and indoor radon concentration: The northern Portugal case study. *Comun. Geológicas* **2021**, *107*, 31–41. [[CrossRef](#)]
41. Leshukov, T.; Larionov, A.; Legoshchin, K.; Lesin, Y.; Yakovleva, S. The Assessment of Radon Emissions as Results of the Soil Technogenic Disturbance. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9268. [[CrossRef](#)]
42. Kashkinbayev, Y.; Bakhtin, M.; Kazymbet, P.; Lesbek, A.; Kazhiyakhmetova, B.; Hoshi, M.; Altaeva, N.; Omori, Y.; Tokonami, S.; Sato, H.; et al. Influence of Meteorological Parameters on Indoor Radon Concentration Levels in the Aksu School. *Atmosphere* **2024**, *15*, 1067. [[CrossRef](#)]
43. Elek, N.İ.; Çam, N.F.; Canbaz Öztürk, B.C. Evaluation of Radon-Induced Radiation Risk in Indoor Environments. *Clean Soil Air Water* **2023**, *51*, 2300124. [[CrossRef](#)]
44. Goudarzi, G.; Zeynab, Z.; Fatahiasl, J.; Tahmasebi, Y.; Ghaedrahmat, Z.; Masiri, G.; Goudarzi, M.; Bashirian, N. On the Concentration of Radon in a Polluted City of the Middle East: An Insight into Its Association with PM Levels, Air Properties, and Risk Assessment. *Process Saf. Environ. Prot.* **2023**, *180*, 181–191. [[CrossRef](#)]
45. Oni, O.M.; Aremu, A.A.; Oladapo, O.O.; Agboluaje, B.A.; Fajemiroye, J.A. Artificial Neural Network Modeling of Meteorological and Geological Influences on Indoor Radon Concentration in Selected Tertiary Institutions in Southwestern Nigeria. *J. Environ. Radioact.* **2022**, *251–252*, 106933. [[CrossRef](#)] [[PubMed](#)]
46. Soldati, G.; Galli, G.; Piersanti, A.; Cannelli, V. Multi-Level Continuous Monitoring of Indoor Radon Activity. *J. Environ. Radioact.* **2022**, *250*, 106919. [[CrossRef](#)]
47. Rey, J.F.; Goyette, S.; Gandolla, M.; Palacios, M.; Barazza, F.; Goyette-Pernot, J.G. Long-Term Impacts of Weather Conditions on Indoor Radon Concentration Measurements in Switzerland. *Atmosphere* **2022**, *13*, 92. [[CrossRef](#)]
48. Yarmoshenko, I.; Malinovsky, G.; Vasilyev, A.; Onishchenko, A. Seasonal Variation of Radon Concentrations in Russian Residential High-Rise Buildings. *Atmosphere* **2021**, *12*, 930. [[CrossRef](#)]
49. E Silva, C.R.; Smoak, J.M.; Da Silva-Filho, E.V. Residential Radon Exposure and Seasonal Variation in the Countryside of Southeastern Brazil. *Environ. Monit. Assess.* **2020**, *192*, 544. [[CrossRef](#)] [[PubMed](#)]
50. Li, X.; Li, W.; Shan, H.; Wang, F. Radon Survey in Office Room and Effective Dose Estimation for Staff. *J. Radioanal. Nucl. Chem.* **2020**, *324*, 561–568. [[CrossRef](#)]
51. Kubiak, J.A.; Basińska, M. Analysis of the Radon Concentration in Selected Rooms of Buildings in Poznan County. *Atmosphere* **2022**, *13*, 1664. [[CrossRef](#)]
52. Hu, J.; Wu, Y.; Saputra, M.A.; Song, Y.; Yang, G.; Tokonami, S. Radiation Exposure Due to ²²²Rn, ²²⁰Rn and Their Progenies in Three Metropolises in China and Japan with Different Air Quality Levels. *J. Environ. Radioact.* **2022**, *244–245*, 106830. [[CrossRef](#)]

53. Soldati, G.; Ciaccio, M.G.; Cannelli, V.; Piersanti, A.; Galli, G. Assessment of Indoor Radon Levels at Multiple Floors of an Apartment Building in the Historic Center of Rome (Italy): A Comprehensive Study. *Environ. Sci. Pollut. Res.* **2024**, *31*, 61660–61676. [[CrossRef](#)]
54. Abdo, M.A.S.; Arhouni, F.E.; Zaimi, M.; Boukhair, A.; Fahad, M. Activity Concentration of Indoor Radon and Its Short-Lived Progeny (^{218}Po , ^{214}Pb , and ^{214}Po) and Their Effect on Atmospheric Ionization Rate in Sana'a, Yemen. *Environ. Pollut.* **2024**, *358*, 124518. [[CrossRef](#)]
55. Elmehdi, H.M.; Ramachandran, K.; Gaidi, M.; Daoudi, K. Diurnal and Seasonal Influence on the Indoor Radon Levels in Dwellings of Sharjah Emirate as Well Its Estimation of Annual Effective Dose. *Case Stud. Chem. Environ. Eng.* **2024**, *9*, 100663. [[CrossRef](#)]
56. Di Carlo, C.; Ampollini, M.; Antignani, S.; Caprio, M.; Carpentieri, C.; Caccia, B.; Bochicchio, F. Extreme Reverse Seasonal Variations of Indoor Radon Concentration and Possible Implications on Some Measurement Protocols and Remedial Strategies. *Environ. Pollut.* **2023**, *327*, 121480. [[CrossRef](#)]
57. Taşköprü, C.; İçhedef, M.; Saç, M.M. Diurnal, Monthly, and Seasonal Variations of Indoor Radon Concentrations Concerning Meteorological Parameters. *Environ. Monit. Assess.* **2023**, *195*, 25. [[CrossRef](#)]
58. Kamalakar, D.V.; Vinutha, P.R.; Kaliprasad, C.S.; Narayana, Y. Seasonal Variation of Indoor Radon, Thoron and Their Progeny in Belagavi District of Karnataka, India. *Environ. Monit. Assess.* **2022**, *194*, 310. [[CrossRef](#)]
59. Yarmoshenko, I.; Zhukovsky, M.; Onishchenko, A.; Vasilyev, A.; Malinovsky, G. Factors Influencing Temporal Variations of Radon Concentration in High-Rise Buildings. *J. Environ. Radioact.* **2021**, *232*, 106575. [[CrossRef](#)]
60. Antignani, S.; Venoso, G.; Ampollini, M.; Caprio, M.; Carpentieri, C.; Di Carlo, C.; Caccia, B.; Hunter, N.; Bochicchio, F. A 10-Year Follow-up Study of Yearly Indoor Radon Measurements in Homes, Review of Other Studies and Implications on Lung Cancer Risk Estimates. *Sci. Total Environ.* **2021**, *762*, 144150. [[CrossRef](#)]
61. Ivanova, K.; Stojanovska, Z.; Djunakova, D.; Djounova, J. Analysis of the Spatial Distribution of the Indoor Radon Concentration in School's Buildings in Plovdiv Province, Bulgaria. *Build. Environ.* **2021**, *204*, 108122. [[CrossRef](#)]
62. Romero-Mujalli, G.; Roisenberg, A.; Córdova-González, A.; Stefano, P.H.P. Indoor Radon Concentration and a Diffusion Model in Dwellings Situated in a Subalkaline Granitoid Area, Southern Brazil. *Environ. Earth Sci.* **2021**, *80*, 555. [[CrossRef](#)]
63. Chobanova, N.; Kunovska, B.; Djunakova, D.; Djounova, J.; Stojanovska, Z.; Angelova, A.; Ivanova, K. Indoor Radon Concentrations in Kindergartens in Three Bulgarian Districts. *Radiat. Environ. Biophys.* **2023**, *62*, 441–448. [[CrossRef](#)]
64. Zaripova, Y.; Dyachkov, V.; Bigeldiyeva, M.; Gladkikh, T.; Yushkov, A. Preliminary Survey of Exposure to Indoor Radon in Al-Farabi Kazakh National University, Kazakhstan. *Atmosphere* **2023**, *14*, 1584. [[CrossRef](#)]
65. Branco, P.T.B.S.; Martín-Gisbert, L.; Sá, J.P.; Ruano-Ravina, A.; Barros-Dios, J.; Varela-Lema, L.; Sousa, S.I.V. Quantifying Indoor Radon Levels and Determinants in Schools: A Case Study in the Radon-Prone Area Galicia–Norte de Portugal Euroregion. *Sci. Total Environ.* **2023**, *882*, 163566. [[CrossRef](#)]
66. Kashkinbayev, Y.; Kazymbet, P.; Bakhtin, M.; Khazipova, A.; Hoshi, M.; Sakaguchi, A.; Ibrayeva, D. Indoor Radon Survey in Aksu School and Kindergarten Located near Radioactive Waste Storage Facilities and Gold Mines in Northern Kazakhstan (Akmola Region). *Atmosphere* **2023**, *14*, 1133. [[CrossRef](#)]
67. Alhamdi, W.A.H. Indoor Radon Monitoring in Various Ventilation Degree in Some Schools of Duhok City, Iraq. *Nucl. Technol. Radiat. Prot.* **2023**, *38*, 64–69. [[CrossRef](#)]
68. Corețchi, L.; Ene, A.; Vîrlan, S.; Gîncu, M.; Ababii, A.; Capatina, A.; Overcenco, A.; Sargu, V. Children's Exposure to Radon in Schools and Kindergartens in the Republic of Moldova. *Atmosphere* **2023**, *14*, 11. [[CrossRef](#)]
69. Ivanova, K.; Chobanova, N.; Kunovska, B.; Djounova, J.; Stojanovska, Z. Exposure Due to Indoor Radon in Bulgarian Schools. *Aerosol Air Qual. Res.* **2022**, *22*, 220279. [[CrossRef](#)]
70. López-Pérez, M.; Hernández, F.; Diaz, J.P.; Salazar, P.A. Determination of the Indoor Radon Concentration in Schools of Tenerife (Canary Islands): A Comparative Study. *Air Qual. Atmos. Health* **2022**, *15*, 825–835. [[CrossRef](#)] [[PubMed](#)]
71. Loffredo, F.; Opoku-Ntim, I.; Meo, G.; Quarto, M. Indoor Radon Monitoring in Kindergarten and Primary Schools in South Italy. *Atmosphere* **2022**, *13*, 478. [[CrossRef](#)]
72. Sá, J.P.; Branco, P.T.B.S.; Alvim-Ferraz, M.C.M.; Martins, F.G.; Sousa, S.I.V. Radon in Indoor Air: Towards Continuous Monitoring. *Sustainability* **2022**, *14*, 1529. [[CrossRef](#)]
73. Davis, E.A.; Ou, J.Y.; Chausow, C.; Verdeja, M.A.; Divver, E.; Johnston, J.D.; Beard, J.D. Associations Between School Characteristics and Classroom Radon Concentrations in Utah's Public Schools: A Project Completed by University Environmental Health Students. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5839. [[CrossRef](#)]
74. Erdogan, M.; Abaka, M.; Manisa, K.; Bircan, H.; Kus, C.; Zedef, V. Indoor Radon Activity Concentration and Effective Dose Rates at Schools and Thermal Spas of Ilgin. *Nucl. Technol. Radiat. Prot.* **2020**, *35*, 339–346. [[CrossRef](#)]
75. Lin, C.-C.; Lin, S.-J.; Li, P.-Y.; Lee, M.-S.; Ting, C.-Y. Radon Levels and Dose Assessment at the Basement Workplaces of Hospitals in Different Regions of Taiwan. *Radiat. Phys. Chem.* **2024**, *218*, 111530. [[CrossRef](#)]
76. Gulan, L.; Stajić, J.M.; Spasić, D.; Forkapić, S. Radon Levels and Indoor Air Quality after Application of Thermal Retrofit Measures—A Case Study. *Air Qual. Atmos. Health* **2023**, *16*, 363–373. [[CrossRef](#)]

77. Elzain, A.-E.A. Assessment of Environmental Health Risks Due to Indoor Radon Levels inside Workplaces in Sudan. *Intern. J. Environ. Anal. Chem.* **2023**, *103*, 1394–1410. [[CrossRef](#)]
78. Ivanova, K.; Dzhunakova, D.; Stojanovska, Z.; Djounova, J.; Kunovska, B.; Chobanova, N. Analysis of Exposure to Radon in Bulgarian Rehabilitation Hospitals. *Environ. Sci. Pollut. Res.* **2022**, *29*, 19098–19108. [[CrossRef](#)]
79. Dhoqina, P.; Xhixha, M.K.; Tushe, K.; Bërdufi, I.; Bylyku, E.; Daci, B.; Prifti, D.; Nafezi, G.; Xhixha, G. Occupational Radiation Dose for Medical Workers at the University Hospital Center “Mother Theresa” in Tirana. *J. Radioanal. Nucl. Chem.* **2021**, *328*, 1109–1114. [[CrossRef](#)]
80. Calvente, I.; Núñez, M.I.; Chahboun, R.C.; Villalba-Moreno, J. Survey of Radon Concentrations in the University of Granada in Southern Spain. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2885. [[CrossRef](#)]
81. E Silva, C.R.; Silva-Filho, E.V. Radon Concentration and Radiation Exposure Levels in Workplace Buildings of Downtown Rio de Janeiro City, SE, Brazil. *J. Radioanal. Nucl. Chem.* **2020**, *326*, 1709–1717. [[CrossRef](#)]
82. Gaskin, J.; Zhou, L.G.; Stainforth, R.; Gutcher, C.; Mekarski, P.; Kassie, R.; Li, K.; Vuong, N.; Whyte, J.; Gauthier, M.; et al. Indoor Radon Trends with Building Code Change in Two Canadian Cities. *J. Environ. Radioact.* **2024**, *280*, 107570. [[CrossRef](#)]
83. Mc Carron, B.; Meng, X.; Colclough, S. An Investigation into Indoor Radon Concentrations in Certified Passive House Homes. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4149. [[CrossRef](#)]
84. Yarmoshenko, I.V.; Malinovsky, G.P.; Zhukovsky, M.V.; Izgagin, V.S.; Onishchenko, A.D.; Vasilyev, A.V. Ra-226 in Building Materials as a Source of Indoor Radon in High-Rise Residential Buildings in Russian Cities. *Sci. Total Environ.* **2024**, *935*, 173492. [[CrossRef](#)]
85. Yarmoshenko, I.V.; Malinovsky, G.P.; Zhukovsky, M.V.; Izgagin, V.S.; Onishchenko, A.D.; Vasilyev, A.V. Relationship between Ra-226 Activity Concentration in Building Materials and Indoor Radon Concentration: An Example of Russian High-Rise Residential Buildings. *J. Environ. Radioact.* **2024**, *272*, 107345. [[CrossRef](#)]
86. Wang, N.; Yang, J.; Wang, H.; Jia, B.; Peng, A. Characteristics of Indoor and Soil Gas Radon, and Discussion on High Radon Potential in Urumqi, Xinjiang, NW China. *Atmosphere* **2023**, *14*, 1548. [[CrossRef](#)]
87. Voltattorni, N.; Gasparini, A.; Galli, G. The Analysis of ²²²Rn and ²²⁰Rn Natural Radioactivity for Local Hazard Estimation: The Case Study of Cerveteri (Central Italy). *Int. J. Environ. Res. Public Health* **2023**, *20*, 6420. [[CrossRef](#)]
88. Hansen, V.; Petersen, D.; Sogaard-Hansen, J.; Rigét, F.F.; Mosbech, A.; Clausen, D.S.; Mulvad, G.; Rønnqvist, T. Indoor Radon Survey in Greenland and Dose Assessment. *J. Environ. Radioact.* **2023**, *257*, 107080. [[CrossRef](#)]
89. Cojocar, C.; Cojocar, P.; Barbu, R.M.; Pinzariu, F.; Cojocar, E. Health Risks in Association with Indoor Radon Exposure in Northeastern Romania. *Int. J. Environ. Sci. Technol.* **2023**, *20*, 5937–5944. [[CrossRef](#)]
90. Shurgashti, S.; Rahmani, A.; Dehdashti, A.; Moeinian, K. Determination of Airborne Radon and Its Relationship with the Type of Residential Buildings in Damghan, Iran. *Int. J. Environ. Sci. Technol.* **2022**, *19*, 9601–9608. [[CrossRef](#)]
91. Ndjana Nkoulou, J.E.; Manga, A.; German, O.; Sainz Fernández, C.; Kwato Njock, M.G. Natural Radioactivity in Building Materials, Indoor Radon Measurements, and Assessment of the Associated Risk Indicators in Some Localities of the Centre Region, Cameroon. *Environ. Sci. Pollut. Res.* **2022**, *29*, 54842–54854. [[CrossRef](#)]
92. Dieu Souffit, G.; Jacob Valdes, M.; Bobbo Modibo, O.; Flore, T.S.Y.; Ateba Jean Félix, B.; Tokonami, S. Radon Risk Assessment and Correlation Study of Indoor Radon, Radium-226, and Radon in Soil at the Cobalt-Nickel Bearing Area of Lomié, Eastern Cameroon. *Water Air Soil Pollut.* **2022**, *233*, 196. [[CrossRef](#)]
93. Reddy, B.L.; Reddy, G.S.; Vinay Kumar Reddy, K.V.K.; Sreenivasa Reddy, B.S. Inhalation Dose Due to Residential Radon and Thoron Exposure in Rural Areas: A Case Study at Erravalli and Narasannapet Model Villages of Telangana State, India. *Radiat. Environ. Biophys.* **2021**, *60*, 437–445. [[CrossRef](#)]
94. Aladeniyi, K.; Arogunjo, A.M.; Pereira, A.J.S.C.; Ajayi, O.S.; Fuwape, I.A. Radiometric Evaluation of Indoor Radon Levels with Influence of Building Characteristics in Residential Homes from Southwestern Nigeria. *Environ. Monit. Assess.* **2020**, *192*, 764. [[CrossRef](#)]
95. Abaszadeh Fathabadi, Z.; Ehrampoush, M.H.; Mirzaei, M.; Mokhtari, M.; Nadi Sakhvidi, M.; Rahimdel, A.; Dehghani Tafti, A.; Fallah Yakhvani, M.; Atefi, A.; Eslami, H.; et al. The Relationship of Indoor Radon Gas Concentration with Multiple Sclerosis: A Case-Control Study. *Environ. Sci. Pollut. Res.* **2020**, *27*, 16350–16361. [[CrossRef](#)] [[PubMed](#)]
96. Zaripova, Y.; Yushkov, A.; Amangeldiyeva, N.; Dyussebayeva, K.; Shaidollina, A. Monitoring the Distribution of Radon Isotopes and Their Decay Products in Almaty. *Phys. Sci. Technol.* **2024**, *11*, 4–13. [[CrossRef](#)]
97. Tiomene, D.F.; Bongue, D.; Ebongue, A.N.; Haman, F.; Penabei, S.; Shouop, C.J.G.; Nkoulou, J.E.N.; Moyo, M.N.; Saïdou, Njock, M.G.K. Radionuclides Distribution in Soils and Radon Level Assessment in Dwellings of Mungo and Nkam Divisions, Cameroon. *Environ. Monit. Assess.* **2024**, *196*, 1038. [[CrossRef](#)]
98. Erzin, S.; Yaprak, G. The Correlation between Indoor and Soil Gas Radon Concentrations in Kiraz District, İzmir. *Environ. Monit. Assess.* **2024**, *196*, 845. [[CrossRef](#)] [[PubMed](#)]

99. Bachirou, S.; Kranrod, C.; Ndjana Nkoulou, J.E.N.; Bongue, D.; Yerima Abba, H.Y.; Hosoda, M.; Kwato Njock, M.G.K.; Tokonami, S. Thoron exposure in the radon-thoron prone area of the Adamawa Region, Cameroon. *Appl. Radiat. Isot.* **2024**, *213*, 111498. [[CrossRef](#)]
100. Djeufack, L.B.; Hamadou, I.; Kranrod, C.; Mishra, R.; Hosoda, M.; Sapra, B.K.; Saïdou; Tokonami, S. Effective Dose Assessment Due to Inhalation of ^{222}Rn , ^{220}Rn , and Their Progeny: Highlighting the Major Contribution of Thoron in a Thoron-Prone Area in Cameroon. *Radiat. Environ. Biophys.* **2024**, *63*, 357–369. [[CrossRef](#)]
101. Loffredo, F.; Capussela, T.; De Martino, F.; Quarto, M. Indoor Radon Measurement in Buildings of A.O.R.N Cardarelli, the Largest Hospital of National Relevance in Southern Italy. *Atmosphere* **2024**, *15*, 815. [[CrossRef](#)]
102. Spasić, D.; Gulan, L.; Vučković, B. Indoor Radon Testing, Effective Dose and Mitigation Measures in a Residential House of a Mining Area. *Atmosphere* **2024**, *15*, 745. [[CrossRef](#)]
103. Tan, W.; Nie, Y. Radon Concentration in Air and Evaluation of the Radiation Dose in Villages near Shizhuyuan, Southern Hunan, China. *Atmosphere* **2024**, *15*, 786. [[CrossRef](#)]
104. Kasić, A.; Sakić, Z.; Kasumović, A. Measurement of Indoor Radon Concentrations and Doses Assessment in the Area of Tuzla Canton, Bosnia and Herzegovina. *J. Radioanal. Nucl. Chem.* **2024**, *333*, 2621–2628. [[CrossRef](#)]
105. Thakur, V.; Singh, K.P.; Joshi, A.; Sharma, S.; Bourai, A.A.; Ramola, R.C. Comparative Study of the Radon and Thoron Concentrations in the Indoor Environment of the Budhakedar Region of the Garhwal Himalaya, India. *J. Radioanal. Nucl. Chem.* **2024**, *333*, 3239–3248. [[CrossRef](#)]
106. Hood, C.O.; Miyittah, M.K.; Odam-Ankrah, C.A.; Abaidoo, K.; Tulasi, D.; Ampontuah, R.S.; Adotey, D.K.; Opoku-Ntim, I. Indoor Radon Monitoring in Building Types of a Periurban Area in Cape Coast Metropolis, Southern Ghana. *Indoor Air* **2024**, *2024*, 8966193. [[CrossRef](#)]
107. Serge, A.B.M.; Didier, T.S.S.; Samuel, B.G.; Kranrod, C.; Omori, Y.; Hosoda, M.; Tokonami, S. Assessment of Radiological Risks Due to Indoor Radon, Thoron and Progeny, and Soil Gas Radon in Thorium-Bearing Areas of the Centre and South Regions of Cameroon. *Atmosphere* **2023**, *14*, 1708. [[CrossRef](#)]
108. Tokonami, S.; Kranrod, C.; Kazymbet, P.; Omori, Y.; Bakhtin, M.; Poltabtim, W.; Musikawan, S.; Pradana, R.; Kashkinbayev, Y.; Zhumadilov, K. Residential Radon Exposure in Astana and Aqsu, Kazakhstan. *J. Radiol. Prot.* **2023**, *43*, 023501. [[CrossRef](#)] [[PubMed](#)]
109. Narsha, L.; Ramanand, V.P.; Achari, S.; Kavasara, M.; Narayana, N. Evaluation of Indoor ^{222}Rn and ^{220}Rn Concentrations in Dakshina Kannada, Karnataka, India. *Environ. Monit. Assess.* **2023**, *195*, 592. [[CrossRef](#)]
110. Lawal, K.M.; Inyang, E.P.; Ibanga, E.A.; Ayedun, F. Assessment of Indoor Radon Gas Concentration in National Open University of Nigeria: A Case Study of Calabar Study Centre. *East Eur. J. Phys.* **2023**, *4*, 371–375. [[CrossRef](#)]
111. Gogoi, P.P.; Barooah, D. Radiological Risk Estimation from Indoor Radon, Thoron, and Their Progeny Concentrations Using Nuclear Track Detectors. *Environ. Monit. Assess.* **2022**, *194*, 900. [[CrossRef](#)]
112. Silva, A.S.; Dinis, M.L. Assessment of Indoor Radon Concentration and Time-Series Analysis of Gamma Dose Rate in Three Thermal Spas from Portugal. *Environ. Monit. Assess.* **2022**, *194*, 611. [[CrossRef](#)] [[PubMed](#)]
113. Kaur, R.; Shikha, D.; Kaushal, A.; Gupta, R.; Singh, S.P.; Chauhan, R.P.; Mehta, V. Measurement of Indoor ^{222}Rn , ^{220}Rn and Decay Products along with Naturally Occurring Radionuclides in Some Monuments and Museums of Punjab, India. *J. Radioanal. Nucl. Chem.* **2021**, *330*, 1357–1364. [[CrossRef](#)]
114. Shikha, D.; Kaur, R.; Gupta, R.; Kaur, J.; Sapra, B.K.; Singh, S.P.; Mehta, V. Estimation of Indoor Radon and Thoron Levels along with Their Progeny in Dwellings of Roopnagar District of Punjab, India. *J. Radioanal. Nucl. Chem.* **2021**, *330*, 1365–1381. [[CrossRef](#)]
115. OlaoOlaoye, M.A.; Ademola, A.K.; Jegede, O.A.; Khalaf, H.N.B.; Mostafa, M.Y.A. Estimation of Radon Excess Lung Cancer near Some Dumpsites in Lagos, Nigeria. *Appl. Radiat. Isot.* **2021**, *176*, 109867. [[CrossRef](#)]
116. Ndubisi, O.A.; Apaemi, B.-K.M.; Barikpe, S.F.; Tamunobereton-Ari, I. Analysis of Indoor Radon Level and Its Health Risks Parameters in Three Selected Towns in Port Harcourt, Rivers State, Nigeria. *J. Nig. Soc. Phys. Sci.* **2021**, *3*, 181–188. [[CrossRef](#)]
117. Khan, M.S. Measurements of Lung Doses from Radon and Thoron in the Dwellings of Al-Zulfi, Saudi Arabia, for the Assessment of Health Risk Due to Ionizing Radiation. *Arab. J. Geosci.* **2021**, *14*, 1101. [[CrossRef](#)]
118. Abood, H.N.; Mohamed, A.A. Indoor Radon and Thoron Concentration and the Associated Effective Dose Rate Determination in Dwellings of Suq Alshouk, Thiqr (Iraq). *NeuroQuantology* **2021**, *19*, 06–10. [[CrossRef](#)]
119. Abdo, M.A.S.; Boukhair, A.; Fahad, M.; Ouakkas, S.; Benjelloun, M. Radon Exposure Assessment and Its Decay Products Aerosols in Some Houses of the Province of El Jadida, Morocco. *Air Qual. Atmos. Health* **2021**, *14*, 129–137. [[CrossRef](#)]
120. Vasidov, A.; Vasidova, S. CR-39 Track Detectors for Measurements of Radon Volume Activity and Exhalation Rates of the New Houses of the Tashkent City. *J. Radioanal. Nucl. Chem.* **2020**, *325*, 391–396. [[CrossRef](#)]
121. Aladeniyi, K. Health Risk Evaluation of Radon Progeny Exposure in Nigerian Traditional Mud Houses. *J. Nig. Soc. Phys. Sci.* **2024**, *6*, 2128. [[CrossRef](#)]
122. Sicilia, I.; Aparicio, S.; González Hernández, M.; Anaya Velayos, J.J.; Frutos, B. Radon Transport, Accumulation Patterns, and Mitigation Techniques Applied to Closed Spaces. *Atmosphere* **2022**, *13*, 1692. [[CrossRef](#)]

123. Choi, J.; Hong, H.; Lee, J.; Kim, S.; Kim, G.; Park, B.; Cho, E.-M.; Lee, C. Comparison of Indoor Radon Reduction Effects Based on Apartment Housing Ventilation Methods. *Atmosphere* **2022**, *13*, 204. [[CrossRef](#)]
124. Altendorf, D.; Grünewald, H.; Liu, T.-L.; Dehnert, J.; Trabitzsch, R.; Weiss, H. Decentralised Ventilation Efficiency for Indoor Radon Reduction Considering Different Environmental Parameters. *Isot. Environ. Health Stud.* **2022**, *58*, 195–213. [[CrossRef](#)] [[PubMed](#)]
125. Song, S.; Bing, S.; Hongxing, C.; Wu, W. Study on the Effect of Air Purifier for Reducing Indoor Radon Exposure. *Appl. Radiat. Isot.* **2021**, *173*, 109706. [[CrossRef](#)]
126. Zhou, L.G.; Berquist, J.; Li, Y.E.; Whyte, J.; Gaskin, J.; Vuotari, M.; Nong, G. Passive Soil Depressurization in Canadian Homes for Radon Control. *Build. Environ.* **2021**, *188*, 107487. [[CrossRef](#)]
127. Jeong, J.; Cho, K. Experimental Study on CO₂ and Radon Mitigations in an Apartment Using a Mechanical Ventilation System. *Buildings* **2023**, *13*, 1439. [[CrossRef](#)]
128. Omirou, M.; Clouvas, A.; Leontaris, F.; Kaissas, I. In-Depth Study of Radon in Water in a Greek Village with Enhanced Radon Concentrations. *J. Environ. Radioact.* **2023**, *264*, 107210. [[CrossRef](#)]
129. Daraktchieva, Z.; Wasikiewicz, J.M.; Howarth, C.B.; Miller, C.A. Study of Baseline Radon Levels in the Context of a Shale Gas Development. *Sci. Total Environ.* **2021**, *753*, 141952. [[CrossRef](#)]
130. Autsavapromporn, N.; Krandrod, C.; Klunklin, P.; Kritsanuwat, R.; Jaikang, C.; Kittidachanan, K.; Chitapanarux, I.; Fugkeaw, S.; Hosoda, M.; Tokonami, S. Health Effects of Natural Environmental Radiation during Burning Season in Chiang Mai, Thailand. *Life* **2022**, *12*, 853. [[CrossRef](#)]
131. Mphaga, K.V.; Utembe, W.; Shezi, B.; Mbonane, T.P.; Rathebe, P.C. Unintended Consequences of Urban Expansion and Gold Mining: Elevated Indoor Radon Levels in Gauteng Communities' Neighboring Gold Mine Tailings. *Atmosphere* **2024**, *15*, 881. [[CrossRef](#)]
132. Gulan, L.; Forkapić, S.; Spasić, D.; Živković Radovanović, J.; Hansman, J.; Lakatoš, R.; Samardzic, S. Identification of High Radon Dwellings, Risk of Exposure, and Geogenic Potential in the Mining Area of the "TREPČA" Complex. *Indoor Air* **2022**, *32*, e13077. [[CrossRef](#)] [[PubMed](#)]
133. Gulan, L. Analysis of Long-Term Monitoring of Radon Levels in a Low-Ventilated, Semi-Underground Laboratory—Dose Estimation and Exploration of Potential Earthquake Precursors. *Atmosphere* **2024**, *15*, 1534. [[CrossRef](#)]
134. Vimercati, L.; Cavone, D.; Delfino, M.C.; De Maria, L.; Caputi, A.; Sponselli, S.; Corrado, V.; Bruno, V.; Spalluto, G.; Eranio, G. Relationships among Indoor Radon, Earthquake Magnitude Data and Lung Cancer Risks in a Residential Building of an Apulian Town (Southern Italy). *Atmosphere* **2021**, *12*, 1342. [[CrossRef](#)]
135. Szczepanik-Scislo, N.; Grządziel, D.; Mazur, J.; Kozak, K.; Schnotale, J. Influence of Human Activity on Radon Concentration, Indoor Air Quality, and Thermal Comfort in Small Office Spaces. *Sensors* **2024**, *24*, 4949. [[CrossRef](#)]
136. Chung, L.K.; Mata, L.A.; Carmona, M.A.; Shubayr, N.A.M.; Zhou, Q.; Ye, Y.; Kearfott, K.J. Radon Kinetics in a Natural Indoor Radon Chamber. *Sci. Total Environ.* **2020**, *734*, 139167. [[CrossRef](#)]
137. Portaro, M.; Rocchetti, I.; Tuccimei, P.; Galli, G.; Soligo, M.; Ciotoli, G.; Longoni, C.; Vasquez, D.; Sola, F. Indoor Radon Surveying and Mitigation in the Case-Study of Celleno Town (Central Italy) Located in a Medium Geogenic Radon Potential Area. *Atmosphere* **2024**, *15*, 425. [[CrossRef](#)]
138. Nunes, L.J.R.; Curado, A. Long-Term vs. Short-Term Measurements in Indoor Rn Concentration Monitoring: Establishing a Procedure for Assessing Exposure Potential (RnEP). *Results Eng.* **2023**, *17*, 100966. [[CrossRef](#)]
139. Maheso, A.M.; Bezuidenhout, J.; Newman, R.T. Indoor Radon Levels in Homes and Schools in the Western Cape, South Africa—Results from a Schools Science Outreach Initiative and Corresponding Model Predictions. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1350. [[CrossRef](#)] [[PubMed](#)]
140. Murphy, P.; Dowdall, A.; Long, S.; Curtin, B.; Fenton, D. Estimating Population Lung Cancer Risk from Radon Using a Resource Efficient Stratified Population Weighted Sample Survey Protocol—Lessons and Results from Ireland. *J. Environ. Radioact.* **2021**, *233*, 106582. [[CrossRef](#)] [[PubMed](#)]
141. IAEA, International Atomic Energy Agency. *National and Regional Surveys of Radon Concentration in Dwellings: Review of Methodology and Measurement Techniques*; IAEA Analytical Quality in Nuclear Applications Series No. 33; IAEA: Vienna, Austria, 2013.
142. Rey, J.F.; Meisser, N.; Licina, D.; Goyette Pernot, J. Performance Evaluation of Radon Active Sensors and Passive Dosimeters at Low and High Radon Concentrations. *Build. Environ.* **2024**, *250*, 111154. [[CrossRef](#)]
143. Warkentin, P.; Curry, E.; Michael, O.; Bjorndal, B. A comparison of consumer-grade electronic radon monitors. *J. Radiol. Prot.* **2020**, *40*, 1258–1272. [[CrossRef](#)]

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