WHITE PAPER

Radon in indoor environments: Risk, measurement and mitigation strategies

Abstract

Radon is a naturally occurring radioactive gas and a leading cause of lung cancer after smoking. Despite its well-established health risks, radon remains under monitored in many buildings due to its invisible and odourless nature. This paper outlines the origin and behaviour of radon, examines its associated health risks based on current scientific evidence, and evaluates mitigation strategies with a focus on the role of continuous monitoring.

In addition, the paper explores the limitations of traditional radon detection approaches, the increasing importance of data driven indoor air quality strategies, and the role of emerging sensing technologies in enabling more proactive and effective risk management across a wide range of building types.

Introduction

Indoor air quality has become a central concern in building design, operation and regulation. While pollutants such as particulate matter, carbon dioxide, and volatile organic compounds are routinely monitored, radon remains comparatively overlooked despite its significant health impact. Growing awareness of healthy buildings, alongside regulatory and environmental pressures, is driving increased focus on environmental exposures that affect occupant wellbeing. In this context, radon represents a critical but often underestimated risk factor.

Radon exposure is responsible for a substantial proportion of radiation dose received by the general population and is recognised as a major environmental health risk globally [1]. In many cases, exposure occurs in domestic and occupational settings without occupants being aware, highlighting the importance of improved detection and management strategies.

Radon: Origin and behaviour

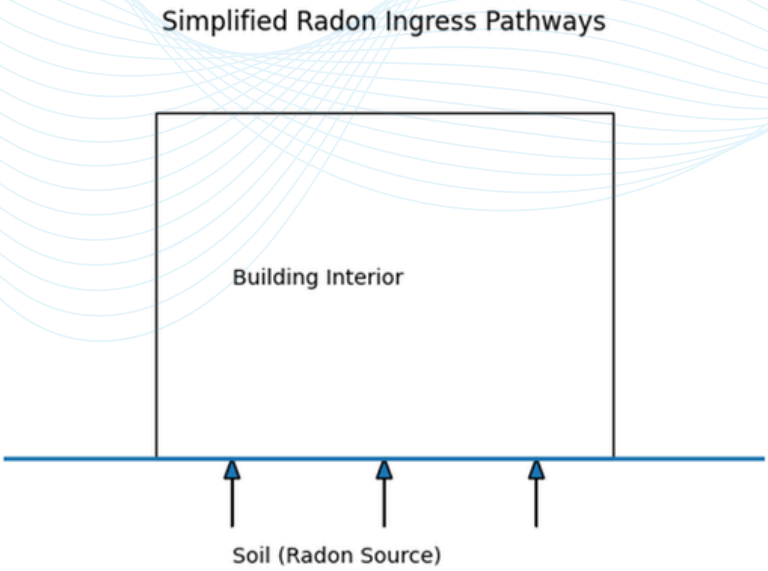
Radon (^{222}Rn) is a radioactive noble gas produced through the decay of uranium naturally present in soil, rock and groundwater[1]. As a gas, it can migrate through porous materials and enter buildings via cracks in floors and walls, construction joints, gaps around service pipes and cavities in building materials. Additional pathways may include suspended floors, drainage systems and poorly sealed service penetrations, all of which can act as conduits for radon ingress.

Once indoors, radon can accumulate, particularly in poorly ventilated or lower-level spaces such as basements and ground floors. The stack effect, where warm air rises and creates negative pressure at lower levels, can further draw radon into buildings from the ground.

Radon concentrations are typically expressed in becquerels per cubic metre. The World Health Organization recommends a reference level of 100 Bq per cubic metre, while the United Kingdom action level is 200 Bq per cubic metre[1,2].

Radon levels are highly variable and influenced by geological conditions, building design and construction, ventilation rates as well as seasonal and meteorological factors. For example, levels are often higher in winter months due to reduced ventilation and increased pressure differentials between indoor and outdoor environments. Short term fluctuations can also occur due to occupancy patterns, heating and ventilation operation, and weather events, reinforcing the need for measurement approaches that capture temporal variability.

Radon is a naturally occurring radioactive gas formed from uranium in the ground. It can seep into buildings through cracks, gaps and structural openings, accumulating indoors especially in poorly ventilated, lower-level areas. Its concentration varies depending on geology, building design and environmental conditions, and is measured in becquerels per cubic metre, with recommended safety thresholds set by health authorities.



Health impacts of radon exposure

Radon is classified as a Group 1 carcinogen by the International Agency for Research on Cancer[3]. The primary health risk arises from inhalation of radon decay products, which emit alpha radiation and damage lung tissue.

When inhaled, radon attaches to airborne particles which leads to deposits in the respiratory tract, where ionising radiation can initiate cellular damage and increase the likelihood of malignant transformation over time.

Epidemiological evidence

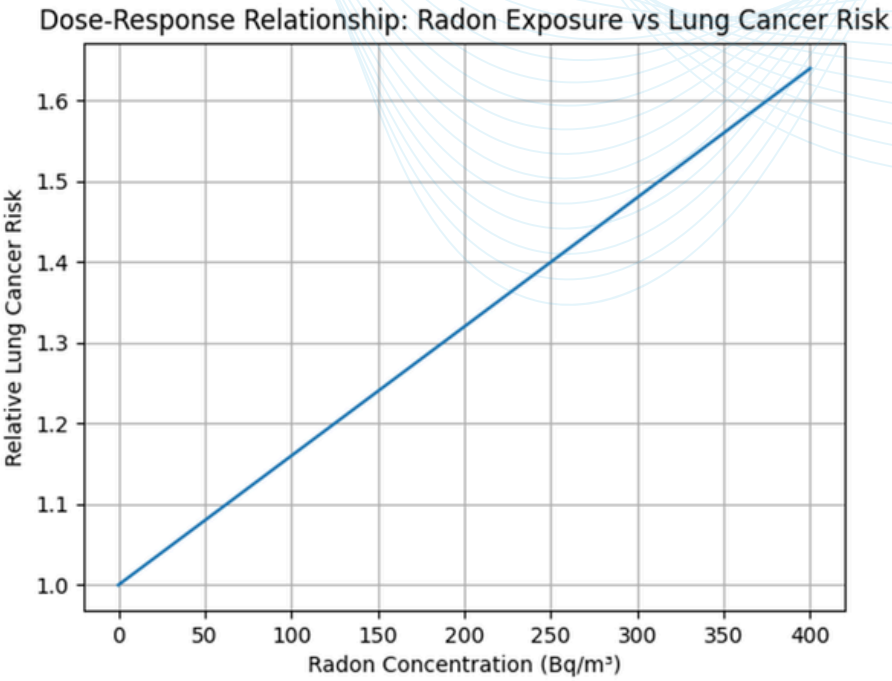
Extensive epidemiological studies have demonstrated a clear association between long term radon exposure and lung cancer incidence. Radon is the second leading cause of lung cancer globally[4]. In the United Kingdom, it contributes to approximately 1,100 lung cancer deaths annually[2]. Lung cancer risk increases by around 16 per cent per 100 Bq per cubic metre increase in long term exposure[5].

Large, pooled analyses, including European case control studies, have confirmed a linear dose response relationship with no clear threshold below which risk is eliminated. This suggests that even relatively low concentrations may contribute to increased risk over extended periods.

Interaction with smoking

The combined effect of radon exposure and smoking is multiplicative, significantly increasing the probability of lung cancer compared to either risk factor alone[1].

For smokers, the absolute risk associated with radon exposure is substantially higher, making radon mitigation particularly important in environments where smoking prevalence is elevated or where vulnerable populations are present.



Radon is a naturally occurring radioactive gas and a proven cause of lung cancer. When inhaled, it releases radiation that can damage lung tissue over time, increasing cancer risk even at relatively low levels. This risk is significantly amplified for smokers, making radon exposure a critical but often unseen health hazard.

Challenges in radon detection and management

Radon presents several unique challenges:

- No sensory detection: colourless, odourless and tasteless.
- Spatial variability: neighbouring buildings can show very different levels.
- Temporal variability: concentrations fluctuate daily and seasonally.

In addition, radon distribution within a single building can vary significantly between rooms and floors, depending on ventilation patterns and building usage.

Traditional radon assessment relies on passive detectors deployed over extended periods, typically one to three months [2]. While effective for establishing average exposure, these methods lack temporal resolution, real time visibility and responsiveness to environmental changes.

As a result, short term spikes or intermittent high concentrations may not be captured, potentially underestimating exposure risk. Furthermore, passive methods do not support ongoing verification of mitigation measures or provide actionable insight for building operators.

Mitigation strategies

Where elevated radon levels are identified, several mitigation techniques are available:

- Ventilation improvements. Increasing air exchange rates reduces indoor radon concentration[1]. This may include natural ventilation or mechanical systems such as mechanical ventilation with heat recovery.
- Sealing entry routes. Sealing cracks and gaps in floors and walls can reduce radon ingress. While rarely sufficient as a standalone solution, it is often used in conjunction with other measures.
- Sub floor depressurisation. Radon sump systems actively extract radon from beneath buildings and are among the most effective mitigation methods[2].

Additional approaches may include positive pressurisation systems, radon barriers in new construction and modifications to building design to reduce ingress pathways.

These approaches are proven to significantly reduce indoor radon concentrations when correctly implemented. However, their effectiveness can vary depending on building characteristics and requires verification through measurement.

The case for continuous radon monitoring

Advances in sensor technology have enabled a shift from periodic testing to continuous monitoring. Continuous radon monitoring provides high resolution temporal data, offers real time alerts for elevated concentrations together with trend analysis to identify patterns. It also provides verification of mitigation effectiveness. In addition, continuous monitoring enables correlation with other indoor air quality parameters such as carbon dioxide, temperature and humidity, helping to identify the underlying drivers of radon variability.

This approach aligns with wider smart building and indoor air quality management strategies, where real time data is used to optimise building performance, improve occupant wellbeing and support compliance with emerging standards.

Technology application

Synetica's enLink IAQ Radon is an example of a continuous monitoring solution designed for deployment across a range of environments. Key capabilities include:

- Continuous radon measurement.
- LoRaWAN connectivity for long range data transmission.
- Multi parameter indoor air quality sensing.
- Flexible installation across building types.

Such systems enable early detection of elevated radon levels, ongoing exposure assessment and data driven mitigation strategies. Continuous monitoring supports a transition from periodic compliance-based testing to proactive risk management.

The integration of connectivity and cloud-based platforms also enables centralised monitoring across building portfolios, supporting facilities managers, consultants and stakeholders in maintaining safe indoor environments at scale.

Synetica's enLink IAQ Radon

Discussion

Traditional radon measurement methods remain valuable for baseline assessment and regulatory purposes. However, they are limited in dynamic or complex environments where radon levels fluctuate.

Continuous monitoring addresses these limitations by providing real time information and enabling ongoing control. It also supports a more holistic approach to indoor air quality, where radon is managed alongside other environmental parameters.

As building performance frameworks increasingly prioritise health, wellbeing and sustainability, the ability to continuously monitor and manage radon will become an important differentiator.

Conclusion

Radon is a significant but often overlooked indoor air quality risk. Its health impacts are well established, and effective mitigation strategies exist. However, successful management depends on accurate and timely data.

Continuous monitoring technologies, such as enLink IAQ Radon, provide the visibility required to detect, understand and manage radon exposure effectively. This represents a shift towards proactive, data driven indoor environmental management.

As awareness, regulation and technology continue to evolve, continuous radon monitoring is likely to become an integral component of comprehensive indoor air quality strategies across residential, commercial and public sector buildings.

References

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Intelligent environmental and energy monitoring solutions from Synetica

Synetica is a leading UK-based provider of smart monitoring technologies designed to help organisations understand and optimise the performance of their environments and energy systems. With a product range tailored for modern commercial, industrial, and institutional spaces, Synetica's solutions enable continuous, data-driven management of air quality, environmental comfort, and energy consumption.

At the heart of Synetica's offering is a suite of high-precision sensors and analytics platforms that deliver real-time visibility into critical indoor metrics. These include measurements of carbon dioxide (CO_2), particulate matter (PM0.1, 0.3, 0.5, 1.0, 2.5, 5.0 and 10), total volatile organic compounds (TVOCs), ozone (O_3), temperature, relative humidity, light levels, and occupancy patterns. All devices can be permanently installed, providing stable and consistent monitoring that goes far beyond occasional spot checks or portable instrumentation.

Synetica's systems are built for seamless integration with building management systems and cloud-based platforms, enabling facilities teams to respond instantly to changes in conditions. Monitoring intervals can be configured to as frequent as every 60 seconds, ensuring that even subtle shifts in air quality or environmental comfort are captured and acted upon. The system also supports automated alerts, allowing building operators to take corrective action before occupant experience or compliance thresholds are compromised.

In addition to environmental monitoring, Synetica offers tools for energy use tracking, allowing users to monitor electricity, gas, and water consumption at highly granular levels. This supports energy efficiency strategies, cost management, and regulatory reporting, and can be customised to support broader sustainability or carbon reduction goals.

All data collected is visualised through intuitive dashboards, offering historical analysis, trend tracking, and exportable reporting. This empowers stakeholders, from facilities managers to sustainability leads, to make informed, evidence-based decisions that improve building performance and occupant wellbeing.

Whether deployed in office buildings, schools, hospitals, retail spaces, or manufacturing environments, Synetica's technologies provide the insight required to create healthier, more efficient, and more resilient spaces. Their systems are designed to support not only compliance and risk mitigation but also the proactive enhancement of environmental quality and operational efficiency.

About us

Synetica was established in 2008 with the simple idea to revolutionise air quality monitoring, energy usage and remote asset monitoring. Our global customer base relies on our expertise to help them reduce emissions and clean up the air they breathe by allowing them to monitor their energy usage and key environmental parameters via the touch of a button.

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