

Title: Radon metrology: Sensor networks for big buildings and future cities

Abstract

Besides public buildings and workplaces, European Council Directive 2013/59/Euratom requires member states to mitigate ^{222}Rn activity concentration in private houses, where the reference level of $300 \text{ Bq}\cdot\text{m}^{-3}$ can be regularly exceeded. Authorities are therefore required to implement mitigation strategies to comply with basic safety standards and to protect citizens from exposure to ionising radiation from ^{222}Rn progenies. A recent study showed that end-users are often unaware of the danger posed by high ^{222}Rn activity concentration in their homes. This project addresses the challenge of establishing activity concentrations of ^{222}Rn and ^{222}Rn progenies in indoor air in large buildings for the city of the future. This will be accomplished by providing fit-for-purpose measurement solutions to improve ^{222}Rn metrology, so strengthening European ^{222}Rn measurement manufacturers operating in this market sector and supporting regulations and standards.

Keywords

Radon metrology, energy saving, radiation protection, Machine Learning, air quality control, big data, internet of things, advanced manufacturing, Council Directive 2013/59/Euratom [1]

Background to the Metrological Challenges

Naturally occurring ^{222}Rn emanates from the ground and can accumulate in buildings to create a risk of lung cancer to the occupants over time. Improving a building's thermal insulation to construct CO_2 neutral houses, also increases the radon activity concentration inside these homes. The basic safety standards for radiation protection implemented by Council Directive 2013/59/Euratom requires ^{222}Rn remediation strategies to be implemented once the indoor activity concentration reaches $300 \text{ Bq}\cdot\text{m}^{-3}$ at any location within the building. To reduce utility costs in large buildings, air exchange system flow reduction is an energy efficient approach but may cause radon levels to increase as although outdoor ^{222}Rn activity concentrations are usually orders of magnitude smaller than indoor concentrations, lack of air flow can cause ^{222}Rn concentrations to build. Better radon mapping during building construction to assess the risks from ^{222}Rn , would also help update the ^{222}Rn map of the European Atlas for Natural Radiation (EANR) which needs updating.

Assuming developers have awareness that the dangers from ^{222}Rn exposure are present in a specific construction area, concentration measurements are usually only made once or, if the presence of ^{222}Rn is detected and mitigation measures implemented, twice (before and after the mitigation). No regular or ongoing measurements are made throughout a building. Project developments should aim to provide construction companies with the opportunity to equip large buildings with sensor networks that utilise artificial intelligence techniques and incorporate new commercially available radon activity concentration sensors with connectivity to the building's sensor network. Radon sensors need development to provide fit-for-purpose fast measurement solutions, with automated acquisition, transmission, and analysis of data coupled with the capability for automatic device status' monitoring to reduce maintenance, repair, and calibration cycle costs.

Research grade state-of-the-art ^{222}Rn activity concentration sensors are too large and expensive to be routinely implemented in buildings. In contrast, commercially available ^{222}Rn activity concentration sensors lack the necessary sensitivity, fast response time and low uncertainty to accurately determine ^{222}Rn activity concentrations below $100 \text{ Bq}\cdot\text{m}^{-3}$ in private homes and workplaces. This results in a high demand for compact and highly sensitive ^{222}Rn activity concentration sensors with low measurement uncertainties at ^{222}Rn concentrations below $100 \text{ Bq}\cdot\text{m}^{-3}$ capable of fast response times and low maintenance requirements. To address this need, proposals are sought that will develop new fast and highly sensitive validated radon sensors, the necessary calibration regime to support their use in intelligent multi-sensor networks install in large buildings such as those anticipated in the city of the future. To enable new radon sensor development,

proposal consortia are encouraged to recruit SME participants to help facilitate new sensor development as current laboratory-based radon monitors require regular performance monitoring and interventions.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement and characterisation of proposal developed new and/or improved existing ^{222}Rn activity concentration measurement detectors and the combining of these into automatic multi-sensor networks that provide regular and reliable indoor ^{222}Rn activity concentration measurements with other sensor building types in an energy efficient regime.

The specific objectives are

1. To develop and assemble, using advanced manufacturing, cost effective and material saving prototype sensors for detecting radon activity concentration based on novel concepts and methods with lowered response time, increased sensitivity and reduced uncertainty compared to existing ^{222}Ra detection devices used in dwellings.
2. To develop traceable, *in-situ* operando calibration procedures for these sensors with targeted measurement uncertainties of less than 10 % at an activity concentration level of $50 \text{ Bq}\cdot\text{m}^{-3}$ after consideration of sensor response time and dynamic linearity testing.
3. To develop a quality assured sensor network suitable for large building monitoring, consisting of the developed sensors and based on the use of artificial intelligence, IoT and digital twins (e.g. ISO 11665-X, etc).
4. To develop an extension of the sensor network from Objective 3 capable of including other existing and potential building sensor networks that incorporates intelligent data analysis and assimilation methods to enable the optimised use of energy, air quality management and radiation protection in a single monitoring system.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the industry, the measurement supply chain (NMI, calibration laboratories), the standards developing organisations (e.g. IEC, ISO), end users in radiation protection and building air quality system manufacturing and via the EMN on Radiation Protection, to support the development of new, innovative products, thereby enhancing the competitiveness of EU industry.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR JRP 16ENV10 metroRADON and 19ENV01 traceRadon projects and how their proposal will build on these.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the 'end user' community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the "end user" community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the radiation protection and air quality instrumentation sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of the Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.