



IAEA

International Atomic Energy Agency

Atoms for Peace and Development



**World Health
Organization**

International Atomic Energy Agency Learning programme: Radon gas

Module 4:

**Developing and Implementing a
Representative Indoor Radon Survey**

Content

- Scope of this module
- Representative radon survey aims
- Population-based surveys
- Geographically-based surveys
- Summary of learning points
- Additional reading

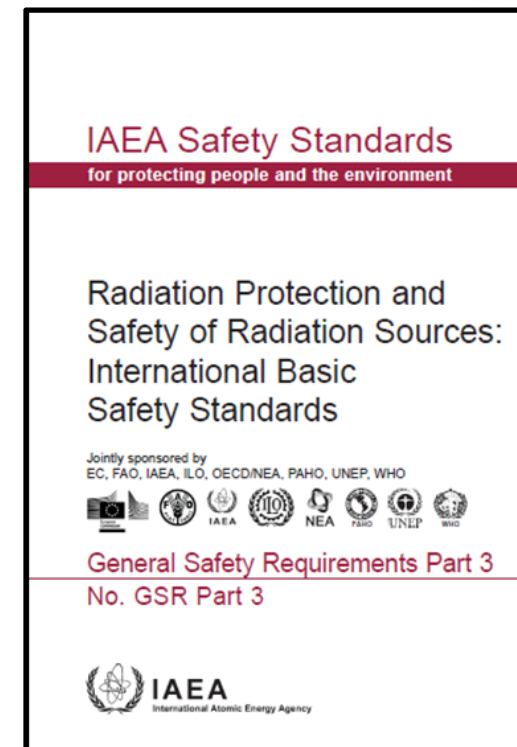
Scope of this Module

- This module covers large scale (national or regional) surveys to evaluate radon in **homes only**, but many of the same considerations also apply to radon surveys in buildings with other uses.
- Similarly, this module does not specifically address surveys of radon in workplaces or in other buildings with high occupancy factors for members of the public (such as kindergartens, schools and hospitals). Such buildings are fewer in number (compared to homes) and it is likely that every such building will be individually assessed rather than sampled in a survey.
- This module focuses on surveys based on direct indoor radon measurement rather than soil gas surveys or other predictive methods.

General Safety Requirements (GSR) Part 3



- GSR Part 3 does not specifically advise that a national radon survey needs to be undertaken, but rather that ‘representative radon surveys’ are necessary.
- Representative radon surveys can be national or regional
- It is recommended that the National Authority establish a working group to consider the scale and nature of a representative survey



Pre-Survey: Existing Data

- Existing Radon Data
 - *Reliability, representativeness*
- Geological Data
 - *Bedrock, soil, aquifers*
 - *Climate data*
- Health data
 - *Statistical data on lung cancer incidence/mortality,*
 - *Smoking prevalence*
- Housing styles/types
 - *Ventilation impacts, crawl space, basements, etc.*
 - *Homes with permanent openings or on stilts*



Pre-Survey: Pilot Study

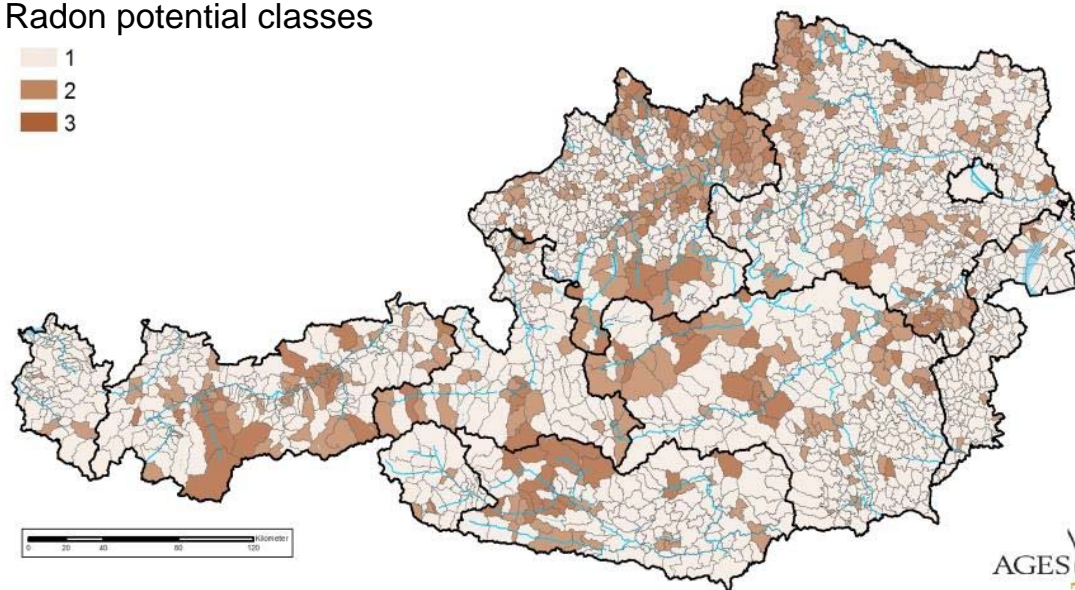
- Small scale and manageable
- Test of logistics
- Test of public reaction and cooperation
- Learning on unexpected issues
- Opportunity to determine seasonal correction factors and background radon concentrations



Representative radon survey – 2 general approaches

- **Exposure risk** determined by a population-based survey
- **Radon prone** areas determined by a geographically-based survey
- A carefully designed survey can, in principle, meet the requirements and objectives of both types of surveys

Radon potential classes



Map basis: 15,035 ÖNRAP radon measurements, Austria

Population weighted (or population-based) survey



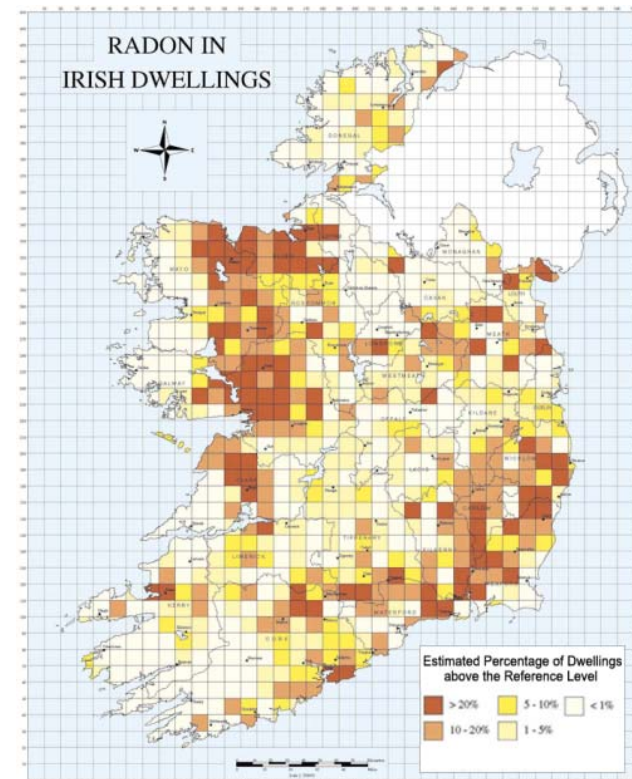
- Aim:
To estimate the frequency distribution of radon values in the country and the average exposure of the population to indoor radon.
- Measured homes have to be representative of the total housing stock → random selection.
- Get statistical advice



Geographically-based survey

- Aim:

To identify those areas within the country where high indoor radon concentrations are more likely to be found
- Measured homes must be based on a geographically-based unit area. The area can be regular (grid square) or irregular (administrative unit) or other spatial unit (geological unit).
- The homes selected for the survey should be representative of those in each area.
- Get statistical advice



Sampling and Sample Numbers

- Simple Random Sampling
 - Random sample from the list of all dwellings or inhabitants
- Stratified Random Sampling
 - Target population is partitioned into separated groups (strata). This may be appropriate where distribution of population is uneven and different strata require different sampling densities
- Cluster or Multi-Stage Sampling
 - Within a region, a random selection of towns is performed, then; within the selected towns, a random selection of homes is performed
- Numbers of Samples
 - Typically <1% of the housing stock
 - Depends on size of population or territory to be surveyed
 - Depends on variability expected and variability accepted



Randomness, Completeness, and Bias

- Be sure that the source list or database is representative and complete
- Be wary of “volunteer” participants
- Be wary of “surrogate lists”
 - For example, landline phone number lists – these may not be random as more homes may not have a landline
- Failure to consider such factors will lead to bias



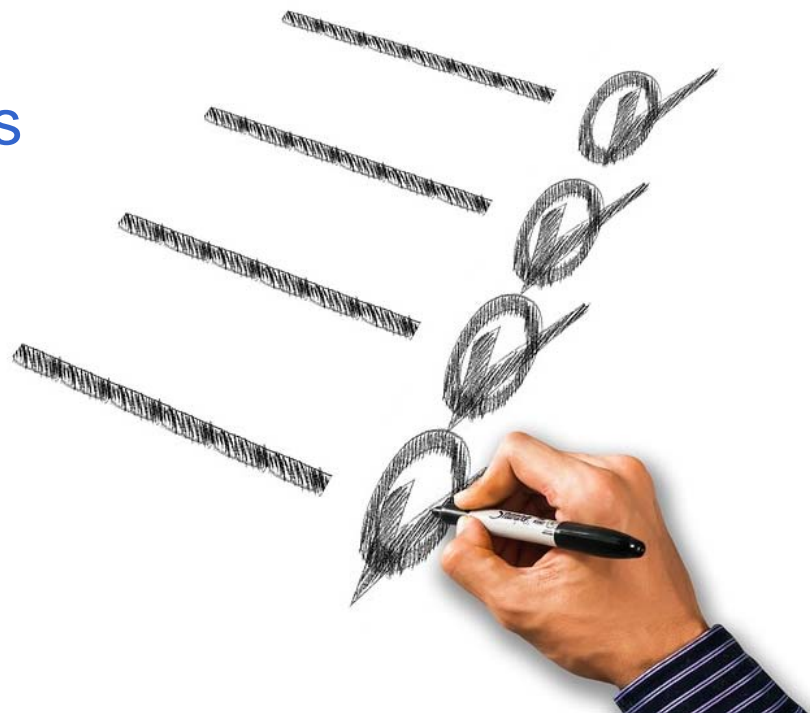
Detectors, Measurement, Placement



- Detector Type
- Measurement Protocols
- Transport and Packaging
- Detector Placement
- Measurement Period
- Quality Assurance and Quality Control
- Data Management
- Reporting and
- Advice to the Public

Questionnaire for Survey

- Opportunity to add value
- House age and construction type
- Ventilation type
- Basement or foundation details
- Heating method
- Daily occupation pattern
- Smoking habits
- Water source
- Permission for data use
- Permission on follow up research



Communication and Engagement

- Pre-survey engagement
 - Letter/info pack, phone call, local media
- Survey engagement
 - Detector pack or direct contact
- During survey
 - Phone call, SMS (text message)
- Post survey
 - Report and advice
 - Further research/follow-up



Data validation and analysis

- Representativeness
 - Check that bias has not entered the data (for example, due to an unknown failure of postal service in one area)
- Log-normality test
 - Check that the frequency distribution of radon concentration is log-normal
- Sampling scheme
 - simple sampling
 - stratified sampling

APPROVED

APPROVED

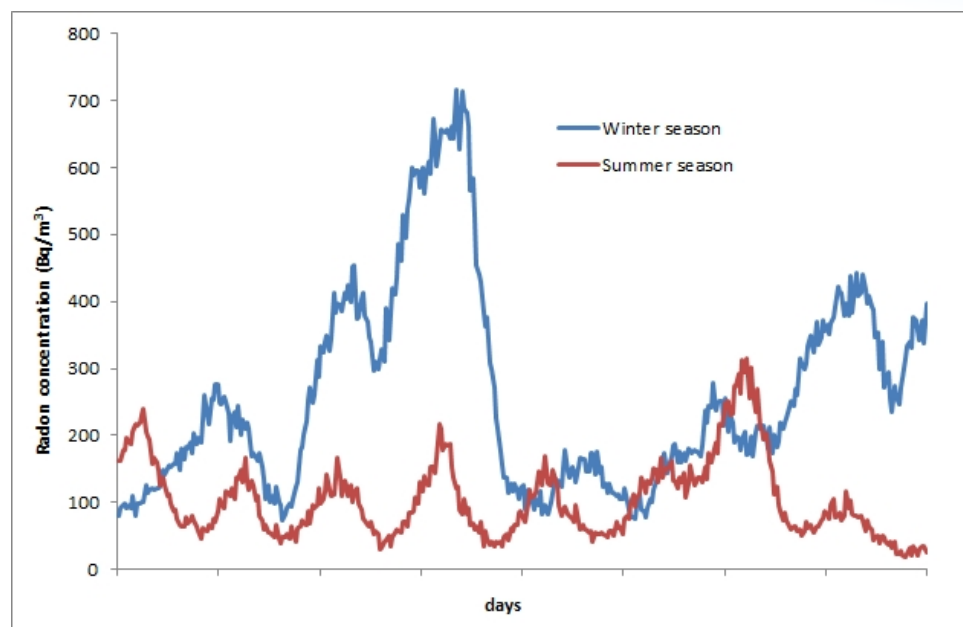
Data correction

Background Radon Concentrations

- Survey
- Adjustment to log normal plot

Seasonal Correction Factor

- 12 month measurements
- Fixed season measurements
- Seasonal correction



Seasonal variation of indoor radon concentration.

Source: SURO: National Radiation Protection Institute of Czech Republic

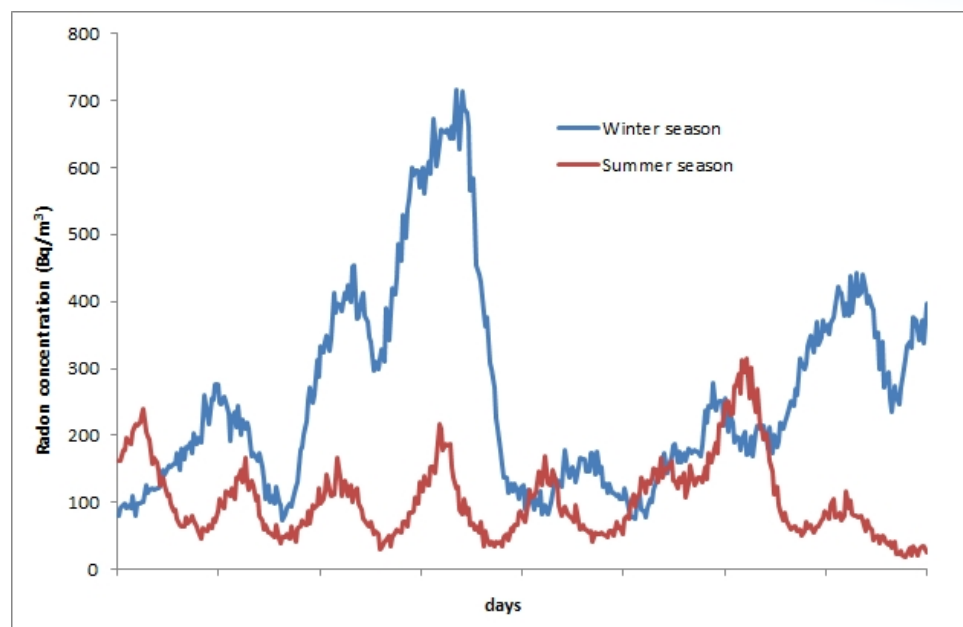
Data correction (continued)

Background Radon Concentrations

- Survey
- Adjustment to log normal plot

Seasonal Correction Factor

- 12 month measurements
- Fixed season measurements
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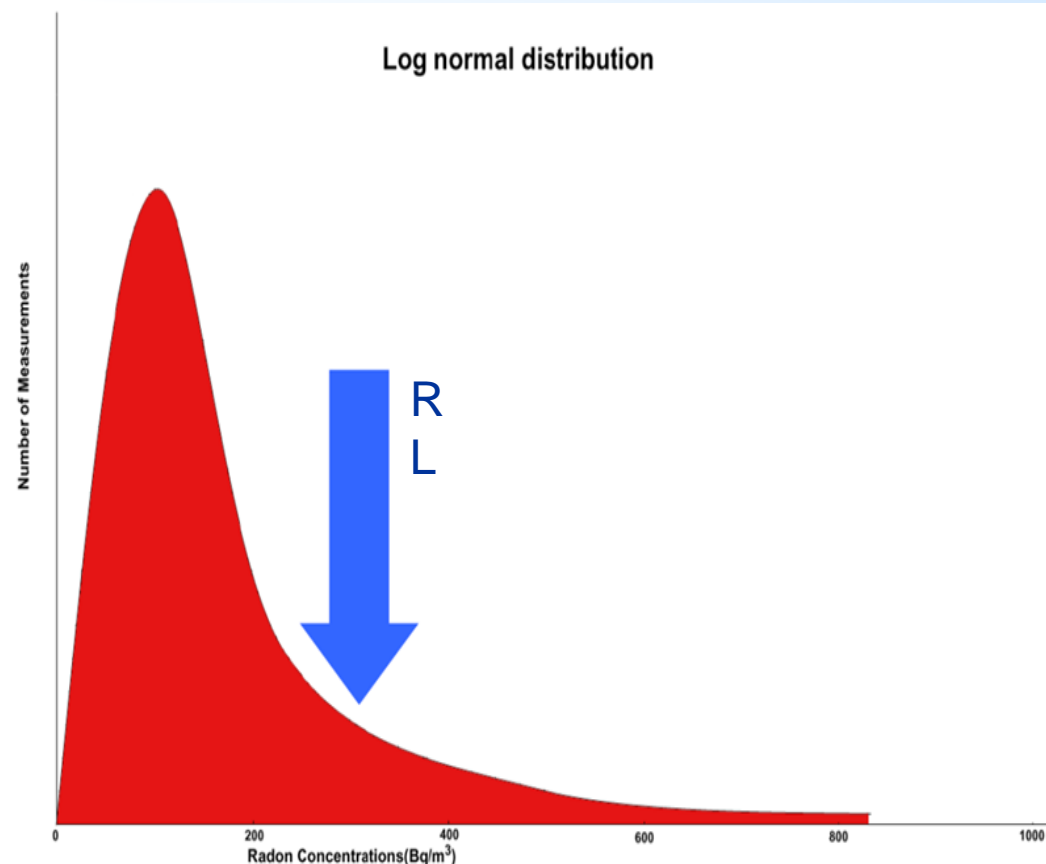


Seasonal variation of indoor radon concentration.

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Data analysis

- Arithmetic mean and standard deviation
- Geometric mean (GM) and geometric standard deviation (GSD)
- Percentage of homes over reference level
 - Knowing GM and GSD, the percentage of dwellings exceeding any reference level (RL) can be estimated by using statistical tables of the area under the standardized normal curve



Mapping the survey data

- Geographical-based survey
- Identify radon prone areas
 - Define “radon prone”
- Benefits of maps
 - Prioritising action
 - Raising awareness
- Risks of maps
 - Boundaries incorrectly interpreted as “safe/unsafe”
 - Incorrectly substituted for radon testing



**Radon risk map = map of radon prone areas = a tool for planning;
it is NOT a predictor of indoor radon concentration**

Soil gas measurements

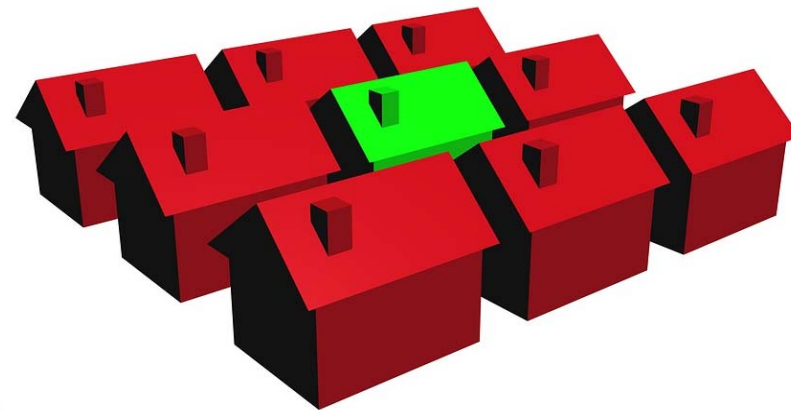
- Direct measurements of radon in soil gas
- Identification of radon-prone areas
- May be correlated with indoor radon concentrations
- Radon modelling
 - Combining different parameters – indoor radon concentrations, soil gas radon concentrations, geological parameters, and aerial radioactivity measurements – can result in a higher definition radon map than might be achieved by survey of indoor radon alone.

Data Management

- National Radon Action Plan - long term
- Survey updates
- On-going data collection
- Data management
 - National authority
 - Private measurement services
- National database

Metrics and Follow-up

- Metrics – lagging indicators
 - Population-based national average indoor radon concentration
 - Lung cancer risk due to radon
- Follow-up interval dictated by rates of radon remediation and rates of new home construction with radon preventative measures



Summary of Learning Points (1)

- GSR Part 3 requires evaluation of radon exposure, if necessary, by undertaking representative radon surveys
- The nature of the representative survey is at the discretion of the national authority and can be informed by review of existing data and/or performance of a pilot study
- Two survey types are described but both can be combined in a single survey: Population-based, to estimate public exposure to radon, and Geographically-based, to identify radon prone areas
- Radon maps can be enhanced with the use of geological and soil gas survey data
- Sampling methods are tailored to the survey requirements and the advice of a statistician is recommended

Summary of Learning Points (2)

- Sampled households should, in all cases, be representative of the whole population
- A questionnaire can be included in the survey strategy to gather relevant additional information
- Effective communication with the survey participants will reduce data losses and lead to more successful outcomes
- Mapping of radon survey data is a valuable tool for policy and planning but maps risk misinterpretation
- A data management system is recommended
- Follow-up survey(s) will be required in due course to assess the progress of the National Radon Action Plan

Further Reading

- International Atomic Energy Agency/AQ/33: *National and Regional Surveys of Radon Concentration in Dwellings: Review of Methodology and Measurement Techniques*
- IAEA (2015). *Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation: Specific Safety Guide*. No. SSG-32, Vienna.
- World Health Organization (2009). *Handbook on Radon: A Public Health Perspective*, Geneva.
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2006 Report, Volume II, Annex E: Sources to effects assessment for radon in homes and workplaces. United Nations ed., New York (2009) and Annex B: Exposures from natural radiation sources. United Nations ed., New York (2000)

Further Reading (2)

- Dubois, G., (2005). *An overview of radon surveys in Europe*, EUR 21892 EN, EC 1–168.
- WHO (2007). *International Radon Project: Survey on radon guidelines, programmes and activities*, WHO/HSE/RAD/07.01.
- Burke, O., Long, S., Murphy, P., Organo, C., Fenton, D. and Colgan, P.A. (2010). *Estimation of seasonal correction factors through Fourier decomposition analysis – a new model for indoor radon levels in Irish homes*. *Journal of Radiological Protection*. 30 433-443.
- An overview of radon surveys in Europe:
(https://rem.jrc.ec.europa.eu/remweb/publications/EUR_RADON.pdf)
- USEPA - Protocols for Radon and Radon Decay Product Measurements in Homes



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