Indoor radon levels and influencing factors in dwellings in France

J.-C. Paillard[1], C. Roudier[1], J.-P. Lucas[2], A. Zeghnoun[1], O. Catelinois[1, 3], P. Pirard[1], J.-P. Gambard[3], C. Mandin[2], D. Laurier[3], A. Lefranc[1], B. Vacquier[1]
1/ French Institute for Public Health Surveillance (InVS), Saint-Maurice, France – 2/ Scientific and Technical Building Institute (CSTB), Champs-sur-Marne, France
3/ Institute for Radiological Protection and Nuclear Safety (IRSN), Fontenay-aux-Roses, France

Introduction

- Radon is classified as a lung human carcinogen by the International Agency for Research on Cancer.
- Between 1,000 to 3,000 lung cancer deaths a year may be attributable to radon exposure in France.
- Radon is the first source of exposure to ionizing radiation, before the medical one.
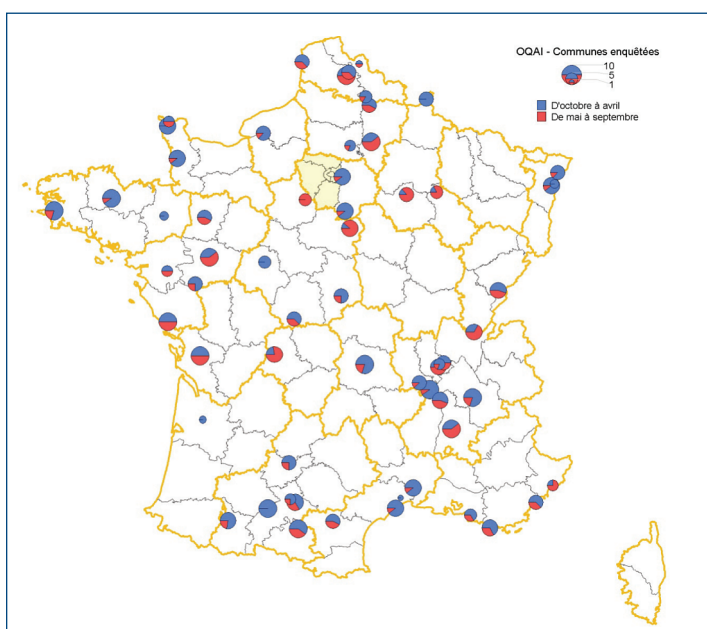
Objectives

The aim of this work was:
- to describe radon levels in continental metropolitan France;
- to study determinants of indoor radon concentrations in a representative sample of French dwellings.

Methods

Study design

- Survey conducted by the Indoor Air Quality Observatory (OQAI) in metropolitan continental France to assess indoor air quality in French dwellings.
- Study period: between October 2003 and December 2005.
- Representative sample of principal residences in France (n=567), distributed among 74 municipalities of 55 departments and 19 regions.

Data collection

- Standardized questionnaires by an interviewer (technical characteristics of the building and living conditions).
- Radon measurement by Kodalpha LR115 detector (2 months in the living room and in one bedroom).
- Type of sub soil geology (4 categories, database of BRGM website).

Statistical analysis

- **Description of radon levels**
  - Estimation of arithmetic and geometric means of radon concentration in dwellings:
    - taking into account a correction factor of seasonal variation, sample design and weighting factors;
    - pearson's correlation and Spearman's rank correlation coefficient calculated between measurements in the bedroom and in the living room.
- **Study of determinants of indoor radon concentration**
  - Use of a generalized linear regression model:
    - log-transformation of radon concentration;
    - taking into account sample design and weighting factors.
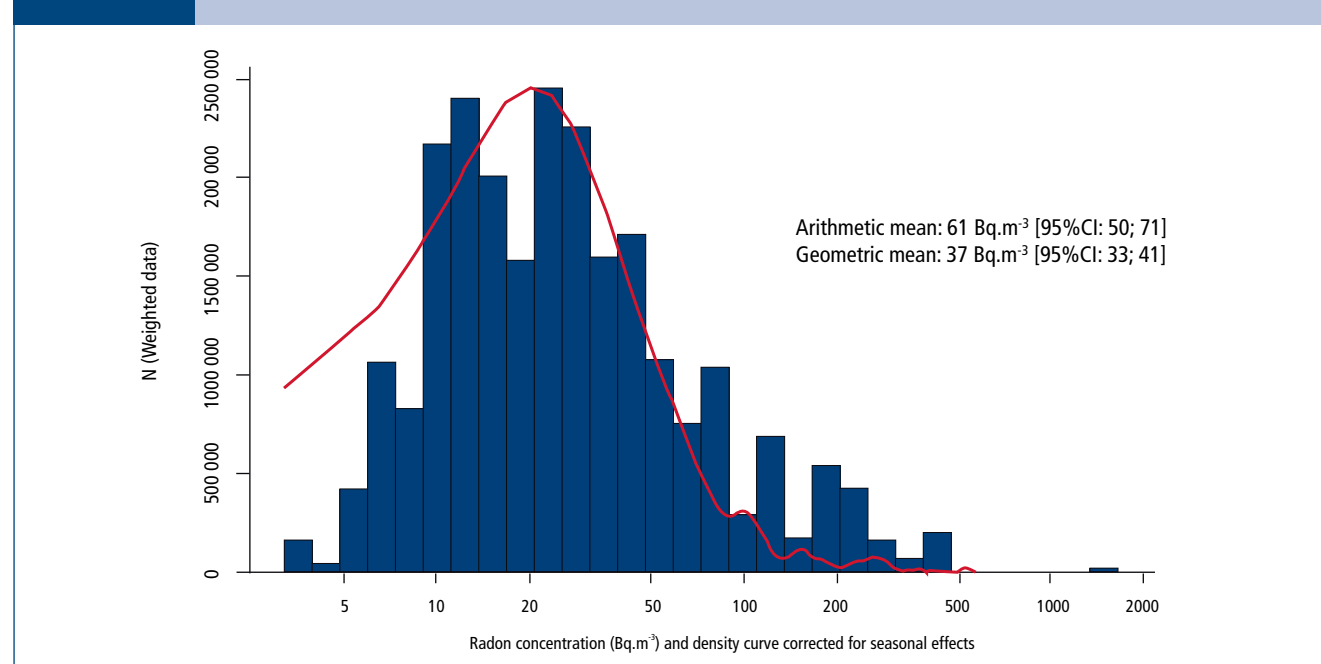
Standard errors and regression models using the survey commands of SAS® 9.1.

Results

Figure — Distribution of the radon concentration in dwellings in continental metropolitan France

Arithmetic mean: 61 Bq.m⁻³ [95%CI: 50; 71]
Geometric mean: 37 Bq.m⁻³ [95%CI: 33; 41]

- High correlation between radon concentration in the bedroom and in the living room with Pearson and Spearman coefficients respectively of 0.83 (p<0.001) and 0.80 (p<0.001).
- The final linear regression model included: construction period, building material, floor, cave communicating with dwelling, garage communicating with dwelling, door and window opening daily duration, air conditioning system, type of air exchange system, heating system, smoking inside, presence of a fireplace, air exchange rate, single glazing rate, joint rate, relative humidity and temperature in the bedroom, density of occupancy, season, and geology.
- The model explained 40% of the global variability of indoor radon concentration.

Table — Factors significantly associated with indoor radon concentration in dwellings in continental metropolitan France

Determinants	β	CI95%
Building material (versus Concrete)		
Wood	0.84	[0.33 ; 1.34]
Brick	0.02	[-0.27 ; 0.30]
Granite	1.44	[0.60 ; 2.28]
Cinderblock	0.03	[-0.16 ; 0.23]
Stone	0.37	[0.05 ; 0.69]
Other	0.23	[-0.09 ; 0.55]
Floor (versus Ground floor)		
First floor	-0.10	[-0.32 ; 0.12]
2nd and 3rd floors	-0.40	[-0.72 ; -0.08]
4th floor and over	-0.23	[-0.53 ; -0.02]
Air conditioning system (versus No)		
Yes	-0.23	[-0.66 ; -0.13]
Heating system (versus No heating)		
Central collective heating	-0.75	[-1.22 ; -0.28]
Central individual heating	-0.18	[-0.59 ; 0.22]
Electric heating	-0.56	[-0.99 ; -0.13]
Urban heating	-0.64	[-1.22 ; -0.06]
Fireplace (versus No)		
Yes	0.19	[0.00 ; 0.39]
Geology (versus Sedimentary)		
Magmatic granitic	0.43	[-0.31 ; 1.18]
Magmatic non granitic	0.70	[0.45 ; 0.94]
Metamorphic	0.69	[0.19 ; 1.18]

Conclusions

- Indoor radon levels are consistent with those observed in the previously available French study.
- The factors found to have a statistically significant association with indoor radon are in overall concordance with findings from other studies.
- This study assessed, for the first time in France, the determinants of radon concentration based on a representative sample of the French dwellings. It allows a better characterisation of the determinants of within-dwellings radon levels in France.
- An updated mapping of geological radon potential in France is currently in progress by IRSN (based on the main parameters influencing the production of radon in the sub soil and the transport of this gas from its source to the soil surface). Considering this updated mapping will be interesting for future analyses of determinants of radon concentration in French dwellings.