EUROPE

ENHIS
EUROPEAN ENVIRONMENT AND HEALTH INFORMATION SYSTEM

RADON LEVELS IN DWELLINGS

FACT SHEET 4.6 ● December 2009 ● CODE: RPG4_Rad_Ex1

Estimated annual mean of radon levels in dwellings and proportion of dwellings with levels above 200 Bq.m^{-3} and 400 Bq.m^{-3}

This summary presents an assessment of the estimated radon levels and proportion of dwellings with annual mean levels of radon above 400 Bq.m^{-3} for existing dwellings and above 200 Bq.m^{-3} for future dwellings in 12 European countries.

KEY MESSAGE

☹ Average radon levels in dwellings vary widely within and between countries. In most countries the world average of 40 Bq.m-3 is exceeded (1). Countries with mainly sedimentary soils (e.g. Germany, the Netherlands, Poland and the United Kingdom) present lower or equivalent averages, whereas those with old granite soils (e.g. Austria, the Czech Republic and Finland) are more prone to radon emissions. If a common action level of 200 Bq.m-3 were to be defined, Austria, the Czech Republic and Finland would have to take remedial measures for more than 10% of the houses, as against under 3.5% in countries with sedimentary soil, for example Poland and the Netherlands.

RATIONALE

The presence of radon in dwellings is an important indicator of the exposure of the population at the beginning and in the course of the process of reducing indoor radon. Considering the linear exposure/response relationship between radon and lung cancer risk, the arithmetic mean is the most relevant indicator to assess the impact on public health.

The radon action levels of 200 and 400 Bq.m-3 allow for international comparisons, since most of the countries comply with the European guideline of 400 Bq.m-3 for existing houses and 200 Bq.m-3 for future dwellings.

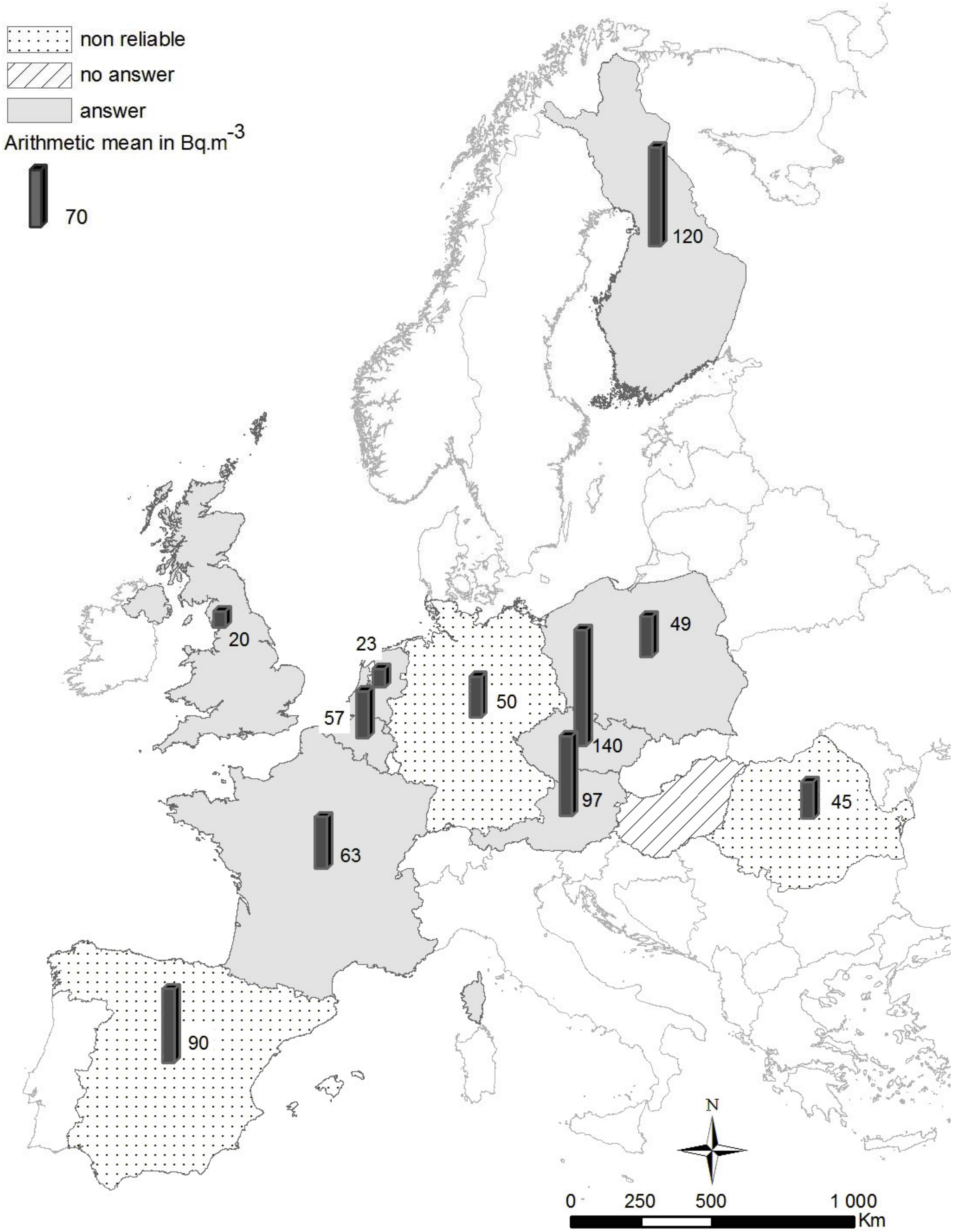
The 200 Bq.m-3 measurement enables a reliable comparison of the proportion of houses that exceed this level in different geographical areas since it is less sensitive to variability from the size of the samples than the 400 Bq.m-3 measurement.

PRESENTATION OF DATA

Fig. 1 shows the estimated arithmetic mean of indoor radon in each country, based on a review of national surveys carried out by the European Commission Joint Research Centre (JRC). There is almost 10 times the difference between the minimum (20 Bq.m^{-3}), found in the Netherlands and the United Kingdom, and the maximum (120–140 Bq.m^{-3}) reported for the Czech Republic and Finland. The maps also display those countries with insufficient or unreliable data.

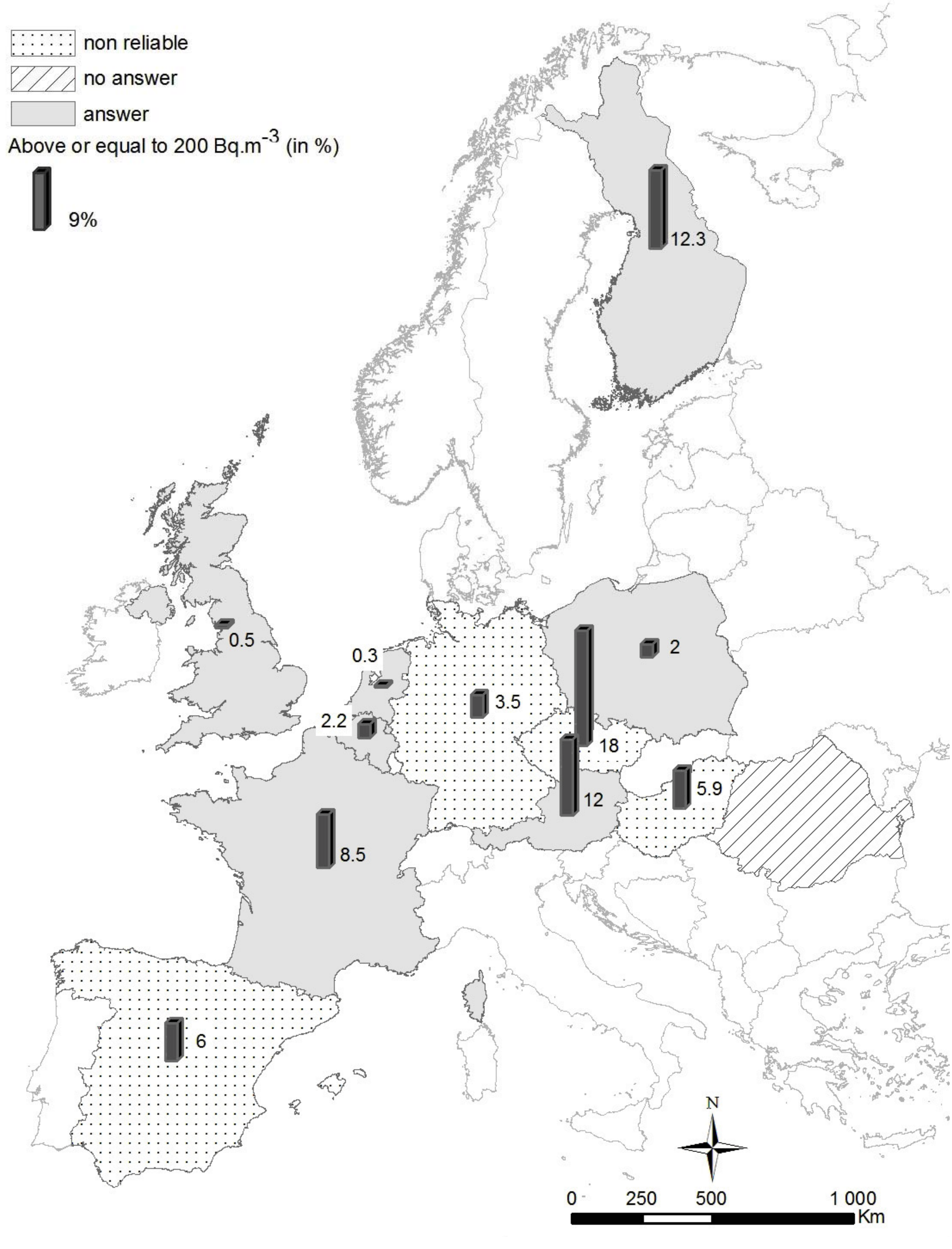
Fig. 2 and 3 show the percentage of radon measurements higher than 200 Bq.m-3 and 400 Bq.m-3. The countries with the highest mean radon levels also have the highest percentage of housing stock above these levels, indicating a higher proportion of houses requiring remedial action.

Fig 1. Estimated annual mean radon levels in dwellings, selected European countries



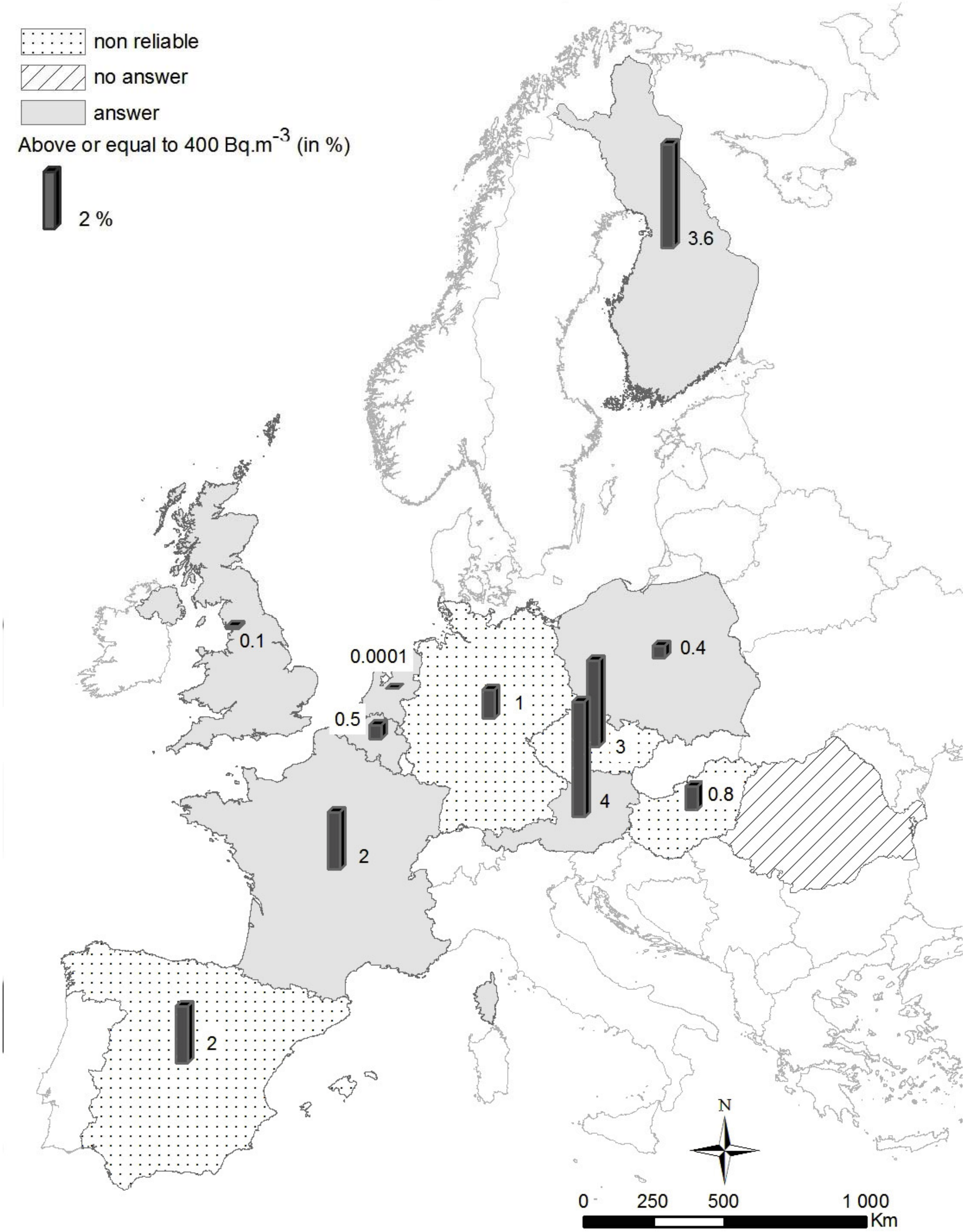
Source: Dubois (2).

Fig. 2. Estimated proportion of dwellings with radon levels ≥200 $Bq.m^{-3}$, selected European countries



Source: Dubois (2).

Fig. 3. Estimated proportion of dwellings with radon levels ≥400 $Bq.m^{-3}$, selected European countries



Source: Dubois (2).

HEALTH AND ENVIRONMENT CONTEXT

Radon is a radioactive gas coming from soils (mainly granites) and accumulating in houses. Radon concentration in air is measured as the number of transformations per second in a cubic metre of air ($Bq.m^{-3}$). One Becquerel corresponds to the transformation (disintegration) of one atomic nucleus per second.

Radon contributes up to 40% of the dose of ionizing radiation received by the population. Studies of cohorts of uranium miners clearly show a linear relation between exposure to radon and risk of lung cancer (3,4). This relation is modified by age, time since exposure and duration of exposure. Pooled analyses of key studies in China, Europe and North America have confirmed that radon in homes contributes substantially to the occurrence of lung cancers worldwide. On the basis of these studies, the International Agency for Research on Cancer (IARC) and the US National Toxicology Program have classified radon as a human carcinogen. There is also discussion of plausible leukemogenicity of radon (5, 6, 7).

Recent findings from case-control studies on lung cancer and exposure to radon in homes completed in many countries allow for substantial improvements in risk estimates and, by pooling the studies, for further consolidation of knowledge. The consistency of the findings from the latest European and North American pooled studies clearly points to a need for global action (8,9). The pooled analysis of key European studies estimated that the risk of lung cancer increases by 16% per 100 $Bq.m^{-3}$ increase in radon concentration (8). The dose–response relation seems to be linear without evidence of a threshold, meaning that the lung cancer risk increases proportionally with increasing radon exposure. Furthermore, the new results show that if a threshold exists, it should not be higher than 150 $Bq.m^{-3}$. With these results and an estimated exposure mean for 29 European countries of 59 Bq.m-3, 9% of deaths from lung cancer per year in Europe were estimated to be attributable to exposure to indoor radon. The pooling studies agree on the magnitude of the risk estimates.

In order to reduce the disease burden associated with radon, it is important that national authorities use methods and tools based on solid scientific evidence and sound public health policy. Mapping and distribution indicators can help to assess the level of burden yet to be expected for radon effects. Most countries have adopted national radon programmes to identify zones of higher concentration and provide information to the public.

On the basis of the new epidemiological evidence, WHO has launched a handbook on indoor radon which focuses on residential radon exposure from a public health point of view (10). Radon is the second most common cause of lung cancer after smoking. There is now strong evidence that radon causes a substantial number of lung cancers in the general population: current estimates of the proportion of lung cancers attributable to radon range from 3 to 14%, depending on the average radon concentration. Lung cancer risk increases proportionally with increasing radon exposure. As many people are exposed to low and moderate radon concentrations, the majority of lung cancers related to radon are caused by these exposure levels rather than by higher concentrations.

POLICY RELEVANCE AND CONTEXT

There is no regulation or directive in Europe concerning radon. Instead, in 1990 the European Commission issued recommendation 90/143/Euratom on the protection of the public against indoor exposure to radon. This recommendation defined 400 $Bq.m^{-3}$ as the level for considering remedial action in existing dwellings and 200 Bq.m-3 as the reference level for new dwellings (11). It has served as a reference for the development of policies against radon exposure in many countries. Although the recommendation sets the framework policy on indoor radon, there are diverse approaches in Europe: some countries do not have any regulations and many others have adopted an indoor radon level within the range 200–400 $Bq.m^{-3}$ as the level for action or the reference level for new buildings. Only a few responsible authorities have developed detailed legislation specifying levels above which financial support for mitigation can be provided.

Radon levels in indoor air can be lowered in a number of ways, from sealing cracks in floors and walls to increasing the ventilation rate of the building. Under-floor sump and extraction methods are considered to be the most efficient. Prevention of radon exposure in new buildings can be implemented through appropriate provisions in the construction phase. National building codes cover the issue of exposure to natural radiation in building construction and ventilation sections.

In addition, all European Union member states already have or are drawing up provisions for implementing basic safety standards for the health protection of the general public, and workers in particular, in case of a significant increase in exposure due to natural radiation sources (including radon) in work places, as laid down in Title VII of Council Directive 96/29/Euratom (12).

In 2006, the JRC launched the Radioactivity Environmental Monitoring (REM) project (13) with the aim of improving the collection, evaluation and harmonization of environmental radioactivity concentrations and the modeling of the migration of radioactivity in the environment. A central activity of REM is the monitoring and mapping of indoor radon (14).

The WHO handbook on indoor radon (10) provides detailed recommendations on reducing health risks from radon and sound policy options for preventing and mitigating radon exposure, such as reliable radon levels measurements, control measures for radon in new dwellings, radon reduction in old dwellings and assessment of their costs and benefits.

Assessment

There are clearly huge differences between countries in terms of exposure to radon in dwellings in Europe. Countries with mainly sedimentary soils have low radon gas concentrations indoors. In our sample this concerns Germany, the Netherlands, Poland and the United Kingdom. Countries with large amounts of granite or uranium-rich soils generally have very high levels of radon.

The wide variations also lead to very different health impacts in countries. As mentioned before, the overall estimate of lung cancer that can be attributed to radon is approximately 9% for Europe. Based on the methodology used in the European pooling study, attributable risk estimates range from about 3% of lung cancer deaths in the Netherlands or the United Kingdom to 21% in the Czech Republic. The public health gain due to remedial action for levels above 200 Bq.m-3, as well as the cost–effectiveness of such action, would also differ greatly between countries.

At present it is impossible to assess the time trends of radon. Improvements in insulation techniques in the context of energy crises may have in fact led to an increase in radon levels in dwellings. Action programmes to reduce radon levels in old and new dwellings may have led to a reduction below certain guidelines, or to changes in radon distribution. The current indicator could serve as a starting point for making an initial assessment at the outset of radon programme activities.

The estimated arithmetic mean in regions or countries would be a good indicator in following up modifications to buildings or other activities aimed at lowering radon levels in dwellings. Monitoring of the proportion of dwellings with radon levels above the point at which action is required will enable the effectiveness of programmes targeted at extreme levels to be evaluated.

The indicator provides a good picture of the discrepancy concerning radon problems between countries and of the proportion of dwellings with levels above the European guidelines. It thus serves a baseline reference for future comparison. Countries with continuing radon programmes can use the information as interim monitoring results.

Data underlying the indicator

Data source
The information comes from the JRC campaign to collect nationally available information for radon mapping in 34 European countries. The focal points in the country institutions in the relevant radon areas answered a questionnaire produced by the JRC. More information about the database used for each country is available on the European Forum on Radon Mapping web site (14).

Description of data
The indicator consists of a presentation per country of three important key values of the distribution of annual radon level in dwellings:

- estimated arithmetic mean of radon concentration
- estimated percentage of dwellings with annual mean levels of radon above 200 Bq.m-3
- estimated percentage of dwellings with annual mean levels of radon above 400 Bq.m-3.

Method of calculating the indicator
The estimated values are given by institutions which deal with indoor radon and maintain information about radon distribution over the country. The survey reference has been quoted as well as its period, the number of dwellings concerned and the method of sampling (Table 1).

Geographical coverage
Austria, Belgium, the Czech Republic, Finland, France, Germany, Hungary, the Netherlands, Poland, Romania, Spain and the United Kingdom.

Period of coverage
The data were collected in 2005 with an addendum in 2008 for Belgium. But the results concern widely differing periods between countries.

Frequency of update
Not specified yet.

Table 1. Sampling table

Variable	Reference survey	Geographical coverage	Survey period	Sampling strategy	No. of dwellings	Measuring equipment	Other measuring technique
Austria	Austrian Radon Project	National	1991–2002	Random and representative	16 000	SSNTD	E-PERM
Belgium	National radon survey	National	1995-2008	Screening then targeted	10 447	Makrofol	
Czech Republic	National radon programme	National	1984–2004	Random and then targeted	150 000	LR115, Kodak	–
Finland	National radon programme	National	1990–1991	Random and representative	3074	Makrofol	–
France	DGS/IPSN survey	National	1983–2000	Systematic screening on geographical basis	12 261	LR115 Kodak	–
Germany	Various regional surveys	National	1978–2003	Varied, preference for geologically specific regions	>50 000	Makrofol	Activated charcoal LSC Activated charcoal gamma spectrometry
Hungary	–	National	1994–2004	Random and targeted	15 602	CR-39	–
Netherlands	National campaign dwellings before 1970s National campaign dwellings 1985–1993	National National	1984 1995–1996	Random, targeted on specific dates of construction	894 952	S1 Kv1 /S2 Fzk	–
Poland	National survey/ regional surveys	National regional	1992–1994 1995–2003	National random/ geologically targeted	2 886 1 212	CR 39/ CR39 - LR115	–
Romania	Local	Regions with high population density	1987–1990 1990–1994 2000	Non-random	119 348 100	NA	–
Spain	Various surveys	Rural regions and areas with potentially high levels	1990–- 2005	Various, no precision	9 800	Terradex KfK	Charcoal detectors
United Kingdom	National survey	National	1988	Random	2 500	NRPB/HPA	–

Note: In the United Kingdom, around 500 000 dwelling measurements have been taken but they were not random and are not used as reference data for the assessment of radon distribution in dwellings.

Data quality
It is important to stress that the radon measurements were not made with a standardized protocol in all countries. In some countries the sample was selected randomly on a national basis, so that the results can be directly extrapolated in order to generate estimates. In others, the samples were not randomly selected and corrections were needed to estimate the radon distribution. Some countries relied on information from regional campaigns and did not give precise descriptions of the methodology used to assess the estimated distribution. Direct comparisons between results are, therefore, to be viewed with great caution.

Radon levels are susceptible to change with modifications to buildings or the renewal of the building stock, or the efficiency of regional or national action programmes. Regular national surveys or targeted surveys of new buildings or buildings of concern are, therefore, necessary to assess the evolution or efficiency of a policy. Coordination between countries is necessary to promote the use of national (and/or regional) survey protocols with a minimum set of standard criteria allowing for direct comparisons. Furthermore, as radon levels are strongly linked to local geological characteristics, the ideal scale to assess and compare radon distribution would be the regional one. Regional mapping based on a standardized assessment protocol could be an excellent tool for making comparisons.

References

1. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. *New York, United Nations, 2000 (http://daccessdds.un.org/doc/UNDOC/GEN/N00/587/20/IMG/N0058720.pdf?OpenElement, accessed 4 April 2007).*
2. *Dubois G.* An overview of radon surveys in Europe. *Luxembourg, Office for Official Publications of the European Communities, 2005 (EUR 21892 EN).*
3. *Lubin J, Boice JD, Edling JC et al.* Radon and lung cancer risk: A joint analysis of 11 underground miner studies. *Bethesda, MD, US National Institutes of Health, 1994.*
4. *Lubin JH, Boice JD, Edling C et al. Radon-exposed underground miners and inverse dose-rate (protraction enhancement) effects.* Health Physics*, 1995, 69:494-500.*
5. *Belson M, Kingsley B, Holmes A. Risk factors for acute leukemia in children: a review.* Environmental Health Perspectives*, 2007, 115:138-145.*
6. *Raashou-Nielsen O., Andersen C.E., Andersen H.P., Gravesen P., Lind M., Schüz J., Ulbak K. Domestic radon and childhood cancer in Denmark. Epidemiology, 2008, 19(4):536-43.*
7. *Olshan A.F. Commentary Are "further studies" really needed? If so, which ones? Epidemiology, 2008, 19(4):545-6.*
8. *Darby S et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies.* British Medical Journal*, 2005, 330(7485):223.*
9. *Krewski D et al. Residential radon and risk of lung cancer: a combined analysis of 7 North American case-control studies.* Epidemiology*, 2005, 16(2):137-145.*
10. WHO handbook on indoor radon - a public health perspective, Geneva, World Health Organization, 2009 (http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf accessed 17 December 2009)
11. Commission recommendation on the protection of the public against indoor exposure to radon (90/143/Euroatom). *Brussels, Commission of the European Communities, 1990 (http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/90143_en.pdf, accessed 4 April 2007).*
12. Council Directive 96/29/Euratom laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. *Brussels, Commission of the European Communities, 1996 (http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9629_en.pdf, accessed 4 April 2007).*
13. *Radioactivity Environmental Monitoring project [web site]. Brussels, European Commission, Joint Research Centre, 2006 (http://rem.jrc.cec.eu.int/, accessed 4 April 2007).*
14. *European Forum on Radon Mapping [web site]. Brussels, European Commission, Joint Research Centre, 2005 (http://radonmapping.jrc.it/index.php?id=36, accessed 4 April 2007).*

Further information

Radon and cancer. Geneva, World Health Organization, 2005 (Fact sheet No. 291; http://www.who.int/mediacentre/factsheets/fs291/en/, accessed 4 April 2007).

Authors of the May 2007 version: Philippe Pirard, National Institute of Public Health Surveillance, Paris, France.
Authors of the *Update 2009*: Philippe Pirard, National Institute of Public Health Surveillance, Paris, France; Dafina Dalbokova, WHO European Centre for Environment and Health, Bonn, Germany.