WHO Handbook on Indoor Radon: A Public Health Perspective

Practical Implications for Healthy Homes Professionals

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Overview

• This presentation focuses on the World Health Organization’s (WHO) guidance to the global community on indoor radon and the science and deliberation around WHO’s recommendations
  – The guidance was developed through over four years of dialogue and consensus of more than 100 scientists and experts from more than 30 countries
Handbook Contents

Editors
- Hajo Zeeb
- Ferid Shannoun

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2. Radon Measurement
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• Acknowledgements
  – Contributors/participants (listed in next slide)
  – Working Group Chairs (listed in a forthcoming slide)
    • And other members of the editorial group
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    • International Atomic Energy Agency
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    • International Commission on Radiological Protection
    • European Commission
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    • U.S. EPA
    • UK Department of Health
    • Radiological Protection Institute of Ireland
Contributors/Participants

More than 100 scientists and radon experts from more than 30 countries

- Argentina
- Austria
- Belgium
- Brazil
- Bulgaria
- Canada
- China
- Czech Republic
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Japan
- Republic of Korea
- Lithuania
- Luxembourg
- Poland
- Romania
- Russia Federation
- Serbia
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States
IRP Working Groups

• Risk assessment
  – Sarah Darby, Oxford U, and Jan Zielinski, Health Canada

• Exposure guidelines
  – David Fenton, Irish Radiation Protection Agency and Francesco Bochicchio, Italian Institute of Health

• Cost-effectiveness
  – Alastair Gray, Oxford University, and Terje Strand, Norwegian Radiation Protection Agency

• Measurement
  – R. William Field, University of Iowa

• Prevention and mitigation
  – William J. Angell, University of Minnesota

• Risk communication
  – James McLaughlin, University College Dublin
Preface

- Radon is second cause of lung cancer in the general population
  - Epidemiological studies provide convincing evidence of an association between indoor radon exposure and lung cancer
    - Even at relatively low concentrations found in residential buildings
- WHO first drew attention to the health effects of residential radon exposure in 1979
- Radon was first classified as a human carcinogen in 1988
  - By the WHO’s International Agency for Research on Cancer
- In 1993, the WHO International Workshop on Indoor Radon
  - Scientists from Europe, North America and Asia proposed
    - A unified approach to control of radon exposures
    - Communication of radon health risks
- In 2005, WHO established the International Radon Project
1. Health Effects

- Current estimates of the proportion of lung cancers attributed to residential radon range from 3 to 14%
  - Depending upon the average radon in the specific country and
  - The calculation method

Note, there is other evidence that residential indoor radon may be responsible for 20% of lung cancers

- Lung cancer risk increases proportionately with exposure
  - As many people are exposed to low and moderate radon concentrations, . . . the majority of lung cancers are caused by these exposures rather than high concentrations
1. Health Effects

Residential Case-Control Studies

• More than 40 residential radon-lung cancer case-control studies have been completed
  – Individually, these studies are generally not definitive
    • The correlation of radon exposure and lung cancer differs considerably from one study to another
      – In part because differing
        » Methodologies assessing smoking-related risks and
        » Quantification of radon exposure histories
  • Therefore, pooled analysis of individual case-control studies has been made
    – 13 European case-control studies analyzed by Darby et al. (2005, 2006)
    – 7 North American case-control studies analyzed by Krewski et al. (2005, 2006)
    – 2 Chinese case-control studies analyzed by Lubin et al. (2004)
## 1. Health Effects

### International Pooling Analysis of Residential Case-Control Studies

<table>
<thead>
<tr>
<th></th>
<th>Number of Studies</th>
<th>Number of Lung Cancers</th>
<th>Number of Controls</th>
<th>Exposure Window (Years)</th>
<th>Increase in Lung Cancer Risk per 100 Bq/m³ Radon Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Based on Rn Measured</td>
</tr>
<tr>
<td><strong>European</strong></td>
<td>13</td>
<td>7,418</td>
<td>14,208</td>
<td>5-35</td>
<td>8%</td>
</tr>
<tr>
<td><strong>North American</strong></td>
<td>7</td>
<td>3,662</td>
<td>4,966</td>
<td>5-30</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Chinese</strong></td>
<td>2</td>
<td>1,050</td>
<td>1,995</td>
<td>5-30</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Weighted Average</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10%</td>
</tr>
</tbody>
</table>
1. Health Effects

Results of Major Radon Studies of Lung Cancer

- Odds ratio vs. Radon concentration (x), pCi/L
  - EPA
    - NA pooled RRs
    - Pooled miners
  - Gansu
    - China pooled RRs
  - Shenyang
    - Pooled European RRs
  - Pooled miners
1. Health Effects

Radon and Diseases Other than Lung Cancer

- Evidence for radon-related mortality from cancers other than lung cancer has been analyzed from the miner studies and strong evidence has not been found
  - Further investigations are focusing on the incidence of leukemia, lymphoma and multiple myeloma
    - A Czech miner study has found a positive association between radon exposure and leukemia
  - A number of other miner studies have examined the relationship between radon and cardiovascular disease but have not found evidence radon is causing heart disease

- About 20 ecological studies of radon exposure in the general population and leukemia and some have found associations
  - Not confirmed through a high quality case-control or cohort study

- A Norwegian ecological study showed an association between indoor radon and multiple sclerosis
  - Not confirmed through a high quality case-control or cohort study
1. Health Effects

Risk Assessment Summary

• Large and recent studies confirm radon in homes increases lung cancer risks
  – Confirm previous studies of miners exposed to radon

• Up to 18% of lung cancers can be attributed to indoor radon
  – Other health effects have not consistently been found
  – Radon is the second leading cause of lung cancer after smoking

• There is no known threshold concentration below which radon is safe

• The majority of lung cancers caused by radon is attributed to low dose exposures of the population
  (Important ~ cost-effectiveness of risk reduction strategies)
# Indoor Rn Concentrations in OECD Countries

(Organization of Economic Cooperation and Development; Bq/m$^3$)

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Austria</td>
<td>99</td>
<td>15</td>
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<tr>
<td>Belgium</td>
<td>48</td>
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<tr>
<td>Canada</td>
<td>28</td>
<td>11</td>
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<tr>
<td>Czech Republic</td>
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<td>Denmark</td>
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<td>Finland</td>
<td>120</td>
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<td>France</td>
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<td>Germany</td>
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<tr>
<td>Greece</td>
<td>55</td>
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<tr>
<td>Hungary</td>
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<td>62</td>
</tr>
<tr>
<td>Iceland</td>
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<td></td>
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<tr>
<td>Ireland</td>
<td>89</td>
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<td>Italy</td>
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<td>52</td>
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<td>Japan</td>
<td>16</td>
<td>13</td>
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<tr>
<td>Luxembourg</td>
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<tr>
<td>Mexico</td>
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<td>90</td>
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<tr>
<td>Netherland</td>
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<td>18</td>
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<td>New Zealand</td>
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<td>Portugal</td>
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<tr>
<td>Republic of Korea</td>
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<td>Slovakia</td>
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<td>Sweden</td>
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<td>Switzerland</td>
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<td>United Kingdom</td>
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<tr>
<td>United States</td>
<td>46</td>
<td>25</td>
</tr>
<tr>
<td><strong>World Average</strong></td>
<td><strong>39</strong></td>
<td></td>
</tr>
</tbody>
</table>
Sources of Annual Radiation Exposure for the General U.S. Population


1987

- All Medical: 15%
- Medical X-ray: 37%
- Medical Tomography: 55%
- Consumer: 15%
- Industrial: 5%
- Background Terrestrial: 5%
- Background Space: 4%
- Nuclear Medicine: 5%
- Radon: 1%

2006

- All Medical: 48%
- Medical X-ray: 37%
- Medical Tomography: 46%
- Consumer: 15%
- Industrial: 5%
- Background Terrestrial: 5%
- Background Space: 3%
- Nuclear Medicine: 5%
- Radon: 1%
Radon Compared to Other Risks


Annual Deaths (U.S.)

- Radon in Homes
- Falls in Homes
- Fires in Homes
- CO in Homes

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2. Radon Measurement

- Measurements for at least 3 months, preferably longer, are needed for estimates of annual average concentrations
  
  - Short-term measurements provide an indication of the actual (annual) radon concentrations
    
    - But short-term measurements are useful for time sensitive situations such as home buying
    
    - . . . and weatherization screening?

- Quality assurance for radon measurement devices is highly recommended in order to ensure the quality of measurement
3. Radon Prevention and Mitigation

- The primary radon prevention and mitigation strategies focus on
  - Sealing radon entry routes and
  - Reversing the air pressure differences between the indoor occupied space and the soil through depressurization techniques

- My critique of this statement is that it could be interpreted that sealing entry routes is, by itself, an appropriate mitigation technique
  - There are differences in opinion about sealing as a stand alone technique especially in existing homes
  - There is consensus soil depressurization is most effective
Active Soil Depressurization (ASD)

- Suction of subslab soil
- 5 cm to 10 cm PVC or metal pipe
- Inline fan outside
- Discharge away from potential exposure
- Performance indicator
- Labeling
- Operating instructions
- Post mitigation testing
3. Radon Prevention and Mitigation

U.S. Radon Mitigation Systems (in 1,000s; Active Soil Depressurization Systems only; assuming 10 year fan life)
The homes sold with elevated radon data are based upon the assumption that 7% of single family houses have elevated indoor radon (cf EPA’s National Residential Radon Survey).
3. Radon Prevention and Mitigation

U.S. Radon Control in New Homes


The New Homes with Rn Control data are based on unqualified and unverified builder representations and therefore, should be suspect—in other words, most certainly these data overstate the number of new homes with effective radon control.
3. Radon Prevention and Mitigation

U.S. New Homes Completed versus New Homes with Rn Control Features? (annual; in 1,000s)
4. Cost-Effectiveness of Radon Control Strategies

- A nation’s choice of radon risk reduction techniques, prevention and testing/mitigation, can be based upon
  - An analysis of cost-effectiveness
    - In this approach, net health-care costs are set in relation to net health benefits for a variety of actions or policies
      » Providing an index which these actions can be prioritized

- Selected analyses indicate that preventive measures in all buildings are cost-effective where more than 5% of the current dwellings have radon concentrations above 200 Bq/m³
  - Prevention tends to be more cost-effective than mitigation
    - In some low risk areas, the measurement costs are sometimes higher than mitigation costs
      » Due to the high number of homes that must have to be tested compared to the proportion of homes mitigated
5. Radon Risk Communication

- Needs to be focused on informing different audiences
  - Recommending radon reduction action
- To develop a set of core messages, a cooperative effort is required involving
  - Technical experts and
  - Communication experts
  - Notably absent is the importance involving cancer survivors
    - www.CanSAR.org
- Radon risk messages should be
  - Kept as simple as possible
  - Quantitative information must be expressed in clear terms
- It is useful to place risk of lung cancer due to radon in comparison with other
  - Cancer risks or
  - Everyday risks in life
5. Radon Risk Communication

Encouraging the Public to Take Action on Reducing Radon

• Disseminating radon risk information to the public is usually insufficient to promote either radon testing or mitigation
  – Rather, a program needs to persuade the public to take action
  – One reason for apathy by some is that they view radon as naturally occurring
  – While radon is natural outdoors, indoors radon concentrations are the result of the way we design and build homes and how occupants use and operate the homes
  – High indoor radon concentrations are a form of technologically enhanced natural radiation

• A colleague, Bill Field, describes indoor radon as a major environmental toxicant equivalent to a radioactive dirty bomb
Why Does It All Matter?

... Because There Victims

Cancer Survivors Against Radon (CanSAR) Founders
6. National Radon Programs

- In general, aim at reduction of
  1. Individual risk for people living with high radon concentrations and
  2. Overall population risk from the national average radon concentrations

- Should focus on
  - The identification of geographic areas at most risk
  - Raising public awareness about the risk of indoor radon exposure

- Key elements of a successful program include
  - Collaboration with other health promotion programs, e.g.,
    - Indoor air quality, anti-tobacco campaigns, cancer control
  - Training of building professionals and others
  - Building codes
  - Measurement during home buying is useful
6. National Radon Programs

National Agencies and Stakeholders Involved in National Radon Program

- Radiation Protection Agencies
- Public Health Agencies
- Geological Institutions
- Construction Standards/Codes Agencies
- Building Research Scientists
- Mitigation Standards/Codes Agencies
- Measurement laboratories
- Provincial/State/Canton Authorities
- Professional Associations
- Media/Press Public Awareness
- Proficiency Tests Providers
- Training Providers

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6. National Radon Programs

National Reference Level (1:2)

• Reference level reflects the maximum accepted average annual radon concentrations in a dwelling. The level may be
  – Strongly recommended (e.g., Canada, Ireland, US, UK) or
  – Mandatory (e.g., Czech Republic, Sweden, Switzerland)
  – In some cases, cites two reference levels, one for existing houses and a lower reference for new construction

• Reference level differs from the term “action level” in as much as the latter gave the impression that radon concentrations below that level were safe

• WHO recommends a reference level as low as reasonably achievable
  – Based upon the latest scientific data, a level of 100 Bq/m$^3$ (2.7 pCi/L) is justified
    • However, if this level cannot be implemented because of country-specific factors, the chosen reference level should not exceed 300 Bq/m$^3$ (8 pCi/L)
6. National Radon Programs

National Reference Level (2:2)

• The decision to set a national reference level needs to take into account the prevailing economical and societal circumstances as well as various national factors such as
  – Distribution of radon
  – The number of existing homes with high radon concentrations
  – Prevalence of smoking

• **Countries with reference levels in the range of 100 to 300 Bq/m$^3$ should first improve their acceptance rate for measurement and mitigation.** For example, in the UK:
  – Keeping the reference level at 200 Bq/m$^3$ while **doubling acceptance and mitigation rates** is estimated to increase the number of lung cancer deaths averted by a factor of 5 whereas
  – Reducing the reference level from 200 to 100 Bq/m$^3$ with the same acceptance and mitigation rates will only increase the number of lung cancer deaths averted by a factor of 2 (Gray et al. 1999)
Where are We at with Radon?

• Radon in U.S. homes:
  • Causes about **21,000** lung cancer deaths (LCD) each year
    • . . . or 1 LCD every **25** minutes
  
• **There are more homes with elevated radon than any time in history!**
  • Today, about **8 million** compared to . . .
    • . . . less than **6 million** in **1990**

• EPA’s radon measurement protocols have not been updated for **18 years** and needed measurement standards have never been written
  • The AARST Standards Consortium has initiated a volunteer-base development of protocols