Radon Dosimetry: Current Status

Alan Birchall and James Marsh

55th Annual Meeting of the Health Physics Society
Salt Lake City, Utah 27 Jun – 1 Jul (2010)

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Radon Dosimetry: Current Status

Structure

1. Introduction
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3. Epidemiological Approach
4. Are the Two Approaches Compatible
5. Current Developments
1. Introduction

What is radon?

- Radioactive noble gas
- From uranium-238 decay chain
- 3.82 day half-life
- Traces of uranium in all rocks and soils
- May diffuse several metres from where it is formed
- Emerges into open air or into houses
1. Introduction

What is radon?

<table>
<thead>
<tr>
<th>Radon gas</th>
<th>$^{222}\text{Rn}$</th>
<th>3.8 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polonium</td>
<td>$^{218}\text{Po}$</td>
<td>3 min</td>
</tr>
<tr>
<td>Lead</td>
<td>$^{214}\text{Pb}$</td>
<td>27 min</td>
</tr>
<tr>
<td>Bismuth</td>
<td>$^{214}\text{Bi}$</td>
<td>20 min</td>
</tr>
<tr>
<td>Polonium</td>
<td>$^{214}\text{Po}$</td>
<td>160 $\mu$s</td>
</tr>
</tbody>
</table>

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1. Introduction

Formation of radon progeny
1. Introduction

Evidence for the risk from radon exposure

- Miners in high-radon mines
- Animals exposed to radon
- People exposed at home
1. Introduction

Why is it important to estimate the risk?

- Radon is the number 1 cause of lung cancer among non smokers.
- Radon causes 100x more deaths than carbon monoxide poisoning
- Radon accounts for the largest component of naturally occurring background dose.
1. Introduction

Why is it important to estimate the risk?

85% NATURAL

- 50% radon gas from the ground
- 10% from food and drink
- 12% cosmic rays

15% ARTIFICIAL

- 13.5% gamma rays from ground and buildings
- 14% medical
- <0.1% nuclear discharges
- <0.1% products
- 0.2% fallout
- 0.2% occupational
1. Introduction

Why is it important to estimate the risk?

- ≈ 2500 deaths per year in UK
- ≈ 20,000 deaths per year in the US
- ≈ 0.5 million per year world-wide

“The biggest geological cause of deaths... including earthquakes! “
1. Introduction

Units: concentration

Radon gas concentration

- pCi/L
- Bq m$^{-3}$

Potential Alpha Energy Concentration (PAEC)

1 Working Level (WL) is any combination of short lived decay products in 1 litre of air which will ultimately emit $1.3 \times 10^5$ MeV of alpha energy.

The PAEC associated with radon progeny in equilibrium with 100 pCi/L of radon gas is about 1WL
1. Introduction

Units: exposure

Radon gas concentration

- Bq m\(^{-3}\) h

Potential Alpha Energy Concentration (PAEC)

1 Working Level (WLM) is an exposure to 1 WL for 1 month (170 h).

Annual exposure of radon gas in a home of 230 Bq m\(^{-3}\) = 1WLM
1. Introduction

How can the risks from radon be assessed?

- **Epidemiological Approach**
  - Exposure to radon (1 WLM)
  - Risk model
  - Excess Risk

- **Dosimetric Approach**
  - Lung dose
  - Effective dose

1. Introduction
   Dosimetric approach

Radon has always had its own publications

All radionuclides (except radon)

ICRP 30
ICRP 60

Radon

ICRP 32
ICRP 65
1. Introduction

Dosimetric approach

The ICRP-66 model was an attempt to rectify this situation, and bring radon in line with other radionuclides.

The ICRP 30 lung model was never really designed for short lived nuclides.

The ICRP-66 model was an attempt to rectify this situation, and bring radon in line with other radionuclides.
2. The Dosimetric Approach

Dosimetric approach

ICRP 66 was designed to deal with short lived radionuclides, so does this change things?

Deposition

Particle Deposition in Respiratory Tract

Clearance

Dosimetry

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2. The Dosimetric Approach

Dosimetric approach

Exposure 1 WLM

Lung model parameters

Ab Dose to bb, BB, AI

\[ A_i = 0.333, \quad w_R = 20 \]

Eq Lung Dose

125 mSv

\[ w_T = 0.12 \]

Effective Dose

15 mSv

Risk = 0.112/Sv, DDREF = 2

RISK

8.4 \times 10^{-4}

Unattached fract 1%

Eq’m factor, F = 0.4

Unattached size .0011 m

Attached size 0.25 m

Breathing rate 1.2 m³h⁻¹

Absorption t₁/₂ 10 h

Morphometry ICRP 66
3. The Epidemiological Approach

Need a risk model

- Estimate exposure (WLM)
- Estimate excess deaths

Risk model

Excess risk
3. The Epidemiological Approach

Need a risk model

Exposure 1 WLM

Data from amalgamated underground minor cohorts

Multiplicative relative risk model with a reduction for time since exposure (ICRP 65)

Reference population J, PR, US, UK, CH (ICRP-60)

Risk 2.8 x 10^{-4}
4. Are the two approaches compatible?

A comparison

Exposure 1 WLM

Lung model parameters

Absorbed Lung Dose

$w_T = 0.12$

$w_R = 20$

Effective Dose

15 mSv

Risk=0.112/Sv

DDREF=2

8.4 x $10^{-4}$

Aerosol parameters

$A_i = 0.333$

Risk model

2.8 x $10^{-4}$
4. Are the two approaches compatible?

Uncertainties

Sarah Darby and Sir Richard Doll

Radiation Protection in Australia 8(4) (1990)

“.... current estimates about the size of the risk associated with exposure in houses of the order of 20 Bq m$^{-1}$ may be too high or they may be too low by a factor of two”
4. Are the two approaches compatible?

**Uncertainties**

![Frequency distribution of E/Pp](image)

- **Effective dose per unit exposure**
- **Frequency distribution of E/Pp**
- Blue: 0.60:0.30:0.10
- Green: 0.33:0.33:0.33
4. Are the two approaches compatible?

*The ICRP resolution*

ICRP 66 (p101, para 356)

“In the case of exposure to radon progeny, since estimates of lung cancer risk for workers (and members of the public) can be made reliably from epidemiologic studies relating lung cancer in miners to radon exposure, the Commission does not recommend the ... [dosimetric approach]”

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4. Are the two approaches compatible?

The ICRP resolution

Exposure of 1 WLM

- Lung Dose
- Eff Dose (15mSv)
- Dose conversion convention
- Comparative dosimetry
- Risk Model
- Population

RISK

8.4 $10^{-4}$  2.8 $10^{-4}$
4. Recent Developments

Exposure of 1 WLM

Lung Dose

Eff Dose (15mSv)

Dose conversion convention

Comparative dosimetry

Risk Model

Population

RISK

8.4 $10^{-4}$

2.8 $10^{-4}$
5. Recent Developments

Dosimetry


- Best estimate of all the latest aerosol parameters
- Best estimate of all the latest lung model parameters

12.5 mSv/WLM
5. Recent Developments

Risk per Sv

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Cancer</td>
<td>Hereditary</td>
</tr>
<tr>
<td>Worker</td>
<td>4.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Public</td>
<td>6.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

$^{(1)}$ Percent risk per Sv
5. Recent Developments

**Epidemiology**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Risk Model</th>
<th>Population (1)</th>
<th>Risk / WLM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before 2000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEIR IV (1988)</td>
<td>BEIR IV</td>
<td>US</td>
<td>3.5 $10^{-4}$</td>
</tr>
<tr>
<td>ICRP-65 (1993)</td>
<td>ICRP65(GSF)</td>
<td>ICRP-60</td>
<td>2.8 $10^{-4}$</td>
</tr>
<tr>
<td><strong>After 2000</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPA (1999)</td>
<td>BEIR VI (2)</td>
<td>US</td>
<td>5.1</td>
</tr>
<tr>
<td>EPA (2003)</td>
<td>BEIR VI (2 and 3)</td>
<td>US</td>
<td>5.4 $10^{-4}$</td>
</tr>
<tr>
<td>Tomasek (2008)</td>
<td>BEIR VI (2)</td>
<td>ICRP-103</td>
<td>5.3 $10^{-4}$</td>
</tr>
<tr>
<td>Tomasek (2008)</td>
<td>Czech/French</td>
<td>ICRP-103</td>
<td>4.4 $10^{-4}$</td>
</tr>
</tbody>
</table>

(1) males/females smokers/non-smokers
(2) exposure-age-concentration risk model
(3) exposure-age-duration risk model

In a recent statement, ICRP has recommended a value of 5.0 $10^{-4}$ for radiation protection purposes.
5. Recent Developments

Exposure 1 WLM

Lung model parameters
Absorbed Lung Dose
\( w_T = 0.12 \)
\( w_R = 20 \)
Effective Dose 1215 mSv

Aerosol parameters
\( A_i = 0.333 \)

Risk model

Risk

5.6 x 10^{-4}

5.2 x 10^{-4}
5. Recent Developments

Dose coefficients

ICRP

Using a revised value of $5 \times 10^{-4}$ per WLM for the lung cancer risk…
and equating with total detriment from ICRP-103

Workers 4.2 x $10^{-2}$ Sv$^{-1}$ 12 mSv WLM$^{-1}$
Public 5.7 x $10^{-2}$ Sv$^{-1}$ 9 mSv WLM$^{-1}$

NCRP

NCRP SC-6-2 have recently updated NCRP Report 93 “Ionizing Radiation Exposure of the United States Population”. The new document, NCRP Report 160 recommends a value of 10 mSv WLM$^{-1}$ for radon exposure
5. Conclusion

• For the first time in a long time we are seeing harmonisation in the way radon is treated, from a radiation protection viewpoint.

• This lends weight to the system of radiological protection for other radionuclides (especially airborne alpha emitters).

THE END