Regulation of Radon – Developments and Challenges

Dr. Japie van Blerk

AquiSim Consulting (Pty) Ltd, PO Box 51777, Wierda Park, Centurion, South Africa
E-mail: aquisim@netactive.co.za

1ST NNR Regulatory Information Conference
05-07 October 2016, Council for Scientific and Industrial Research (CSIR), Pretoria, South Africa
Content

• Introduction

• Revised Dose Conversion Factor for Radon Inhalation

• Implication for Mining and Mineral Processing Operations

• South African Context: Regional Radiological Public Safety Assessments

• Underground Worker Exposure in Mines
  – Contribution from Jozua Ellis from AngloGold Ashanti

• Conclusions
Introduction

- Recognise the important role of organisations and institutions in radiation protection of members of the public and workers
  - UNSCEAR – Scientific information and their contributes to the overall framework for the protection of human health and the environment from exposure to ionizing radiation
  - IAEA through the safety standards
  - ICRP for the recommendations published to ensure protection against ionizing radiation
Introduction

• Mining and Mineral Processing Operations
  – Can be complex, consisting of multiple facilities and activities, which may serve as sources of radiation exposure

  – Radon gas is released from different types of facilities (for example)
    • Tailings storage facilities, waste rock dumps and other NORM stockpiles
    • Upcast ventilation shafts
    • Contaminated soil or land
    • Backfilled mine areas

  – Rate of release and subsequent atmospheric dispersion of radon and its progeny depends on a number of factors, resulting in a spatially distributed airborne radon concentration (in units of Bq.m\(^{-3}\))

  – Inhalation of radon gas and its progeny (indoors and outdoors) contributes to the annual total effective dose to members of the public
    • Often the dominant contributor
    • Determining factor in the public radiation protection programme
Dose Conversion Factor

- Epidemiological studies and the association between lung cancer and exposure to radon and its progeny led to the review of the radon dose conversion factor.

- ICRP Publication 115 recommends a lifetime excess absolute risk of $5 \times 10^{-4}$ per WLM as the nominal probability coefficient for radon- and radon-progeny-induced lung cancer.

- Replacing the Publication 65 value of $2.8 \times 10^{-4}$ per WLM.
### Dose Conversion Factor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indoors</th>
<th>Outdoors</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium Equivalent Concentration</td>
<td>5.56E-06</td>
<td></td>
<td>(mJ.m(^{-3})) per (Bq.m(^{-3}))</td>
</tr>
<tr>
<td>Radon progeny conversion</td>
<td>3.54</td>
<td></td>
<td>(mJ.h.m(^{-3})) per (WLM)</td>
</tr>
<tr>
<td>ICRP Publication 65 proposed a nominal risk coefficient</td>
<td>2.80E-04</td>
<td>2.80E-04</td>
<td>WLM(^{-1})</td>
</tr>
<tr>
<td>Risk detriment as per ICRP Publication 60</td>
<td>7.30E-02</td>
<td>7.30E-02</td>
<td>Sv(^{-1})</td>
</tr>
<tr>
<td>Effective dose per unit exposure to radon</td>
<td>3.84</td>
<td>3.84</td>
<td>mSv per WLM</td>
</tr>
<tr>
<td>Dose conversion for effective dose per unit exposure</td>
<td>1.08</td>
<td>1.08</td>
<td>(mSv.h(^{-1})) per (mJ.m(^{-3}))</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>6.02E-06</td>
<td>6.02E-06</td>
<td>(mSv.h(^{-1})) per (Bq.m(^{-3}))</td>
</tr>
<tr>
<td>Equilibrium factor</td>
<td>0.40</td>
<td>0.60</td>
<td>[-]</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>2.41E-06</td>
<td>3.61E-06</td>
<td>(mSv.h(^{-1})) per (Bq.m(^{-3}))</td>
</tr>
</tbody>
</table>

- **7000 hours indoors** 1.69E-02 mSv per Bq.m\(^{-3}\)
- **1760 hours outdoor** 6.36E-03 mSv per Bq.m\(^{-3}\)
- **Total** 2.32E-02 mSv per Bq.m\(^{-3}\)
### Dose Conversion Factor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indoors</th>
<th>Outdoors</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium Equivalent Concentration</td>
<td>5.56E-06</td>
<td></td>
<td>(mJ.m⁻³) per (Bq.m⁻³)</td>
</tr>
<tr>
<td>Radon progeny conversion</td>
<td></td>
<td>3.54</td>
<td>(mJ.h.m⁻³) per (WLM)</td>
</tr>
<tr>
<td><strong>ICRP Publication 115</strong> proposed a nominal risk coefficient</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>WLM⁻¹</td>
</tr>
<tr>
<td>Risk detriment as per ICRP <strong>Publication 103</strong></td>
<td>5.70E-02</td>
<td>5.70E-02</td>
<td>Sv⁻¹</td>
</tr>
<tr>
<td>Effective dose per unit exposure to radon</td>
<td>8.77</td>
<td>8.77</td>
<td>mSv per WLM</td>
</tr>
<tr>
<td>Dose conversion for effective dose per unit exposure</td>
<td>2.48</td>
<td>2.48</td>
<td>(mSv.h⁻¹) per (mJ.m⁻³)</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>1.38E-05</td>
<td>1.38E-05</td>
<td>(mSv.h⁻¹) per (Bq.m⁻³)</td>
</tr>
<tr>
<td>Equilibrium factor</td>
<td>0.40</td>
<td>0.6</td>
<td>[-]</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>5.51E-06</td>
<td>8.27E-06</td>
<td>(mSv.h⁻¹) per (Bq.m⁻³)</td>
</tr>
</tbody>
</table>

- **7000 hours indoors**: 3.86E-02 mSv per Bq.m⁻³
- **1760 hours outdoor**: 1.45E-02 mSv per Bq.m⁻³
- **Total**: 5.31E-02 mSv per Bq.m⁻³
Dose Conversion Factor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indoors</th>
<th>Outdoors</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equilibrium Equivalent Concentration</td>
<td>5.56E-06</td>
<td></td>
<td>(mJ.m(^{-3})) per (Bq.m(^{-3}))</td>
</tr>
<tr>
<td>Radon progeny conversion</td>
<td>3.54</td>
<td></td>
<td>(mJ.h.m(^{-3})) per (WLM)</td>
</tr>
<tr>
<td>ICRP Publication 115 proposed a nominal risk coefficient</td>
<td>5.00E-04</td>
<td>5.00E-04</td>
<td>WLM(^{-1})</td>
</tr>
<tr>
<td>Risk detriment as per ICRP Publication 103</td>
<td>5.70E-02</td>
<td>5.70E-02</td>
<td>Sv(^{-1})</td>
</tr>
<tr>
<td>Effective dose per unit exposure to radon</td>
<td>8.77</td>
<td>8.77</td>
<td>mSv per WLM</td>
</tr>
<tr>
<td>Dose conversion for effective dose per unit exposure</td>
<td>2.48</td>
<td>2.48</td>
<td>(mSv.h(^{-1})) per (mJ.m(^{-3}))</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>1.38E-05</td>
<td>1.38E-05</td>
<td>(mSv.h(^{-1})) per (Bq.m(^{-3}))</td>
</tr>
<tr>
<td>Equilibrium factor</td>
<td>0.40</td>
<td>0.6</td>
<td>[-]</td>
</tr>
<tr>
<td>Dose factor for inhalation of radon</td>
<td>5.51E-06</td>
<td>8.27E-06</td>
<td>(mSv.h(^{-1})) per (Bq.m(^{-3}))</td>
</tr>
</tbody>
</table>

- 7000 hours indoors: 3.86E-02 mSv per Bq.m\(^{-3}\)
- 1760 hours outdoor: 1.45E-02 mSv per Bq.m\(^{-3}\)
- Total: 5.31E-02 mSv per Bq.m\(^{-3}\)  
  
  Factor 2.3 higher
Implication for Mining and Mineral Processing Operations
Implication for Mining and Mineral Processing Operations (ICRP 65 value)

35 μSv.year\(^{-1}\) - 80 μSv.year\(^{-1}\)
Implication for Mining and Mineral Processing Operations (ICRP 115 value)

80 μSv.year\(^{-1}\) - 182 μSv.year\(^{-1}\)

[Map showing areas with radon inhalation dose to adults in μSv.year\(^{-1}\).]
South African Context: Regional Assessments
South African Context: Regional Assessments

West Wits Area

[Map showing the West Wits Area with labels for Mooirivierloop, Carletonville, Elandsfonteinspruit, and Kraalkopspuit]
South African Context: Regional Assessments

Free State Gold Fields Area
South African Context: Regional Assessments

[Image of a map showing various locations such as Skoonspruit, Palmietspuit, Stilfontein, Koekemoerspruit, and the Vaal River. A highlighted area labeled KOSH Area is also shown.]
What is the implication of the revised dose conversion factors for neighbouring operations, in terms of the dose constraint and dose limit for public radiation protection, on a regional basis?
South African Context: Regional Assessments
South African Context: Regional Assessments (ICRP 65 value)
South African Context: Regional Assessments (ICRP 115 value)
Underground Worker Exposure in Mines

Contribution from Jozua Ellis
Senior Environmental Manager at AngloGold Ashanti
Underground Worker Exposure In Mines

The following graph shows the average, 90\textsuperscript{th} percentile and average radon concentrations in one of our so-called special case mines since 2004; the red line indicating the radon concentration equivalent to \(~20\text{mSv/a or }100\text{mSv/5y.}\)

Based on current dose conversion factors we have to apply limited administrative controls by moving a small number of workers to lower risk areas during the year. Should the conversion factor be revised by a factor of between 2 and 3 as recommended it would have a significant impact our ability to maintain underground mining operations without major disruption.

The ventilation systems of the mines have been optimised and when considering the depth and age of some of the mines further improvements reduce radon concentration to an equivalent of 2 to 3 times is highly unlikely – it is just not possible to get more air into the mine from surface at a rate required to dilute radon concentrations to the levels required.
Underground Worker Exposure in Mines

![Graph showing radon concentration trends in Great Noligwa Special Case Areas](image-url)
Mines have improved the underground radon concentrations over time and it would be irresponsible to adopt the new regulations without extensive engagement with the mining industry.

As we understand, it appears that the increased risk is based on the fact that provision has been made for smokers in the recent recommendations – something which has always been explicitly excluded as it was viewed as voluntary behaviour for which operators of facilities could not be held accountable for.

The compounding risk of radon and smoking is not disputed and has been well known for many decades and should be considered in educating the general public and radiation workers on radiation exposure and more specifically the increased risk from radon when smoking.
Conclusion

• ICRP 115 recommended value will have a significant influence on compliance dose assessment calculations (~2.3 higher) for mining and mineral processing operations, as expected.

• Even more so in areas with neighbouring operations, where compliance with the public dose constraint and even the public dose limit may become challenging.
  – How do we communicate these revised exposure levels to members of the public?

• With radon and radon-progeny being the dominant contributor to the total effective dose, regional assessments become even more important to demonstrating regulatory compliance, and to ensure that members of the public are protected.
  – Will have an influence on the scope and implementation of public radiation protection programmes.
Conclusion

• Future regulation of radon and its progeny for public radiation protection purposes, require

  – Guidance on appropriate selection and application of radon dose coefficients
  – Guidance on how the revised levels should be communicated to members of the public
  – Framework for regional radiological public safety assessments
Underground Worker Exposure In Mines: Conclusions

The message from my side to the workshop is that the recommendations will have a significant impact of both our underground and public exposures and should not be considered without extensive engagement and understanding of the impacts.

The exact reasons for possible changes in conversion factors should also be well communicated and understood by the public and workers – the credibility of the radiation protection regime will be seriously questioned if we all of a sudden tell people their risk from radon exposure has been underestimated by a factor of two to three for many decades; which is not true.

It is the way it is applied in dose limitation or constraints that might change.
Thank you for your Attention!