Radiation exposure due to NORM industries

Malcolm Crick, Secretary UNSCEAR
Joint RASSC/WASSC topical session
Challenges in regulating NORM industries, 22 June 2016
• Aim is to appreciate an overview of exposures arising from different NORM scenarios to help in judging priorities

  – Occupational exposure

  – Public exposure
Based on UNSCEAR 2008 report

- Acknowledgements
  - Lead writers: E.Rochedo, D.Melo (Brazil)

- Based on survey data up to around 2002
- Literature up to 2007
- Report approved by UNSCEAR 2008
- Published in 2010
Trends in occupational exposure

Annual collective dose

EVALUATING RADIATION SCIENCE FOR INFORMED DECISION-MAKING

unscear.org

UNSCEAR 2008 Report
Occupational exposures due to natural sources

Annual collective dose

UNSCEAR 2008 Report
Contributors to occupational exposure

- Coal mining, 45%
- Other mining (except U), 37%
- Other workplaces, 16%
- Aircrew, 2%

Annual collective dose around 37,000 man Sv to about 13 million (average about 3 mSv)

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Exposure characteristics in mining

- Mining ores can contain significant levels of radionuclides from uranium and thorium decay chains.
- Raw materials, by-products, end products may expose workers, who have little appreciation of radiation protection.
- Main sources of exposure in mining are inhalation of radon; inhalation and ingestion of long-lived radionuclides in ore dust; external irradiation.
- Numbers of miners declining.
- Mainly male.
Underground coal miners

Table 52. Annual doses to underground coal miners in China [C12]

<table>
<thead>
<tr>
<th>Type of coal mine</th>
<th>Average annual effective dose (mSv)</th>
<th>Collective dose (man Sv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large-sized</td>
<td>0.28</td>
<td>280</td>
</tr>
<tr>
<td>Medium-sized</td>
<td>0.55</td>
<td>550</td>
</tr>
<tr>
<td>Small-sized</td>
<td>3.3</td>
<td>13 200</td>
</tr>
<tr>
<td>Bone-coal</td>
<td>10.9</td>
<td>545</td>
</tr>
<tr>
<td>Average</td>
<td>2.4</td>
<td>14 600</td>
</tr>
</tbody>
</table>

Most of exposure from inhalation of radon and progeny

### Table 53. Occupational exposure in underground gold mines in South Africa [W17]

<table>
<thead>
<tr>
<th>Year</th>
<th>Average annual dose (mSv)</th>
<th>Number of workers</th>
<th>Number of workers receiving doses of &gt;20 mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>6.3</td>
<td>258 080</td>
<td>12 904</td>
</tr>
<tr>
<td>1998</td>
<td>4.9</td>
<td>232 500</td>
<td>2 325</td>
</tr>
<tr>
<td>1999</td>
<td>5.4</td>
<td>175 333</td>
<td>5 260</td>
</tr>
<tr>
<td>2000</td>
<td>7</td>
<td>123 333</td>
<td>3 700</td>
</tr>
</tbody>
</table>

Underground phosphate mine

• Abu-Tartor, largest phosphate mine in Egypt
  – Average annual effective dose
    • Internal exposure 11 mSv
    • External exposure 9 mSv

• Three mines in Eastern Desert:
  – 107-182 mSv due to radon

• Other Egyptian mines
  – 70 mSv (12 – 140 mSv) due to radon/thoron

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Gas and oil extraction

- $^{226}\text{Ra}$ and $^{228}\text{Ra}$ brought to surface during production
- Radon gas + plate-out from $^{210}\text{Pb}$
- Radioactive scales and sludges
- Internal hazard for workers + higher gamma exposure rate
- A few to a hundred $\mu\text{Sv/h}$ dose rate around equipment
- Annual dose about 1 mSv mainly external, very few data

UNSCEAR 2008 Report
Other NORM industries

- Welders using thoriated welding electrodes
- Phosphate fertilizer production
- Zircon milling
- Rare earth processing

- Relatively small numbers of people
- Doses of several millisieverts annually
- Data sparse
Workplaces other than mines

Table 56. Occupational exposure in Germany due to radon inhalation in workplaces other than mines
Data from the UNSCEAR Global Survey of Occupational Radiation Exposures

<table>
<thead>
<tr>
<th>Workplace</th>
<th>Period</th>
<th>Monitored workers (10^3)</th>
<th>Measurably exposed workers (10^3)</th>
<th>Annual collective effective dose (man Sv)</th>
<th>Average annual effective dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Monitored workers</td>
</tr>
<tr>
<td>Spas</td>
<td>1995–1999</td>
<td>0.002</td>
<td>0.002</td>
<td>0.01</td>
<td>4.77</td>
</tr>
<tr>
<td></td>
<td>2000–2002</td>
<td>0.004</td>
<td>0.002</td>
<td>0.01</td>
<td>4.09</td>
</tr>
<tr>
<td>Waterworks</td>
<td>1995–1999</td>
<td>0.128</td>
<td>0.075</td>
<td>0.24</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td>2000–2002</td>
<td>0.081</td>
<td>0.047</td>
<td>0.11</td>
<td>1.39</td>
</tr>
<tr>
<td>Tourist caves and visitor mines</td>
<td>1995–1999</td>
<td>0.135</td>
<td>0.101</td>
<td>0.31</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>2000–2002</td>
<td>0.131</td>
<td>0.087</td>
<td>0.23</td>
<td>1.76</td>
</tr>
</tbody>
</table>

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Variations that affect evaluation

- Recording of dose values less than MDL
- Technique for measuring external exposure (e.g. TLD, film, electronic dosimeter, glass dosimeter)
- Assignment of dose values for missing periods
- Evaluation of anomalies, such as unexpectedly high or low values
- Subtraction of background doses
- Protocol as to who should be monitored and in what categories
- Whether or not internal exposures are included
- Reliability of individual monitoring data
- UNSCEAR used 9 nSv/Bq h m⁻³ for radon dose conversion
Summary for occupational exposure

- Data so sparse that no meaningful trends on global exposures
- Collective dose around 40,000 man Sv annually
  - Perhaps 17,000 man Sv from coal mining
  - 14,000 man Sv from other mining
  - 6,000 man Sv from radon in other workplaces
- Average individual dose about 3 mSv
  - Wide variation depending on local circumstances
  - Some mines give rise to several tens of millisievert annually, depending on type of mine, geology and working conditions (ventilation)
Nine categories for public exposure

- uranium mining and milling
- metal mining and smelting
- phosphate industry
- coal mines and power generation from coal
- oil and gas drilling
- rare earth and titanium oxide industries
- zirconium and ceramic industries
- applications using natural radionuclides (typically radium and thorium)
- disposal of building material
Uranium mining and milling

- Open pits, underground mines, in situ leaching
- Mill tailings
  - Radon and progeny to atmosphere
  - $^{226}$Ra to liquid pathways ($^{238}$U, $^{230}$Th, $^{210}$Pb)
- Committee estimated average 25 µSv annually for most countries
- Care about reuse of land for building
- Currently being updated and re-evaluated
Metal mining and smelting

- Sparse data, very site-specific
- Inhalation of dust and radon
- Contamination of groundwater with radium isotopes
- External exposure to slag with high thorium content
- e.g. Assessment for gold mine in South Africa

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Assessed dose to nearby populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingestion of water</td>
<td>0.04 mSv</td>
</tr>
<tr>
<td>Ingestion of fish</td>
<td>0.09 mSv</td>
</tr>
<tr>
<td>Ingestion of terrestrial foods</td>
<td>0.002 mSv</td>
</tr>
<tr>
<td>Inhalation of radon</td>
<td>0.04 mSv</td>
</tr>
<tr>
<td>Inhalation of dust</td>
<td>0.02 mSv</td>
</tr>
</tbody>
</table>

Phosphate industry

- Processing may generate emissions with $^{238}\text{U}$ and $^{226}\text{Ra}$
- Local dump sites for phosphogypsum, phosphate fertilizer use, gypsum for building material, radon in building sites
- Slag from producing phosphorous used for constructing roads and houses in USA; led to assessed upper doses of around 1 mSv annually
## Typical public exposures from NORM

### UNSCEAR 2008 Report

#### Table 13. Doses to members of the public due to the industrial release of NORM in the United Kingdom [W6]

<table>
<thead>
<tr>
<th>Industry</th>
<th>Discharge route</th>
<th>Pathway</th>
<th>Annual dose (μSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Critical group</td>
</tr>
<tr>
<td>Coal-fired power station</td>
<td>Atmospheric releases via stack</td>
<td>All</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Building material made from ash</td>
<td>Radon inhalation</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External</td>
<td>900</td>
</tr>
<tr>
<td>Oil and gas extraction</td>
<td>Authorized discharges to sea, and scales</td>
<td>Ingestion of seafood and external exposure due to fishing gear</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Gas-fired power station</td>
<td>Atmospheric releases via stack</td>
<td>All</td>
<td>0.75</td>
</tr>
<tr>
<td>Steel production</td>
<td>Atmospheric releases via stack</td>
<td>All</td>
<td>&lt;100</td>
</tr>
<tr>
<td></td>
<td>Building material made from slag</td>
<td>Radon inhalation</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External</td>
<td>800</td>
</tr>
<tr>
<td>Zircon sands</td>
<td>Atmospheric releases via stack</td>
<td>Inhalation</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
Summary for public exposure

- Doses up to few millisieverts annually for few scenarios, e.g. sludges from water treatment as fertilizers, use of waste products for building material
- No consistent approach to make good global assessment of inventories and exposures
- Conventional mining leads to huge volumes of material with enhanced NORM, making challenge for disposal and site restoration
- Diversity of ores with low levels of radionuclides from uranium and thorium chains – concentrated in products, by-products and wastes
- Public exposure normally low, but considerable numbers of people can be exposed
Current UNSCEAR work

- Much work has been done by others over the past decade on characterizing exposures to workers and public from NORM

- UNSCEAR is:
  - conducting new occupational survey
  - updating assessment of exposures from electricity production
  - planning new public exposure surveys

- Will need to decide on what dose conversion factor for radon it will apply for global assessment
Thank you

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