Health Effects from Chernobyl

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Chernobyl Accident (1986)

“..the foremost nuclear catastrophe in human history” IAEA (1996)

“..its magnitude and scope, the size of the affected populations, and its long-term consequences make it, by far, the worst industrial disaster on record” IAEA/WHO (2005)

“..radioactivity released ~200 times that from Hiroshima or Nagasaki” WHO/IPHECA (1995)
Chernobyl Fallout
## Doses from Chernobyl (2006)


<table>
<thead>
<tr>
<th>Source</th>
<th>Size</th>
<th>Average Dose (mSv)</th>
<th>Collective Dose (Person Sv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidators*</td>
<td>240,000</td>
<td>100</td>
<td>24,000</td>
</tr>
<tr>
<td>High contam areas*</td>
<td>270,000</td>
<td>50</td>
<td>13,500</td>
</tr>
<tr>
<td>Low contam areas*</td>
<td>5.2 m</td>
<td>10</td>
<td>52,000</td>
</tr>
<tr>
<td>Evacuees in 1986*</td>
<td>116,000</td>
<td>33</td>
<td>3,800</td>
</tr>
<tr>
<td>Rest of Europe**</td>
<td>600 m</td>
<td>~0.4</td>
<td>240,000</td>
</tr>
<tr>
<td>Rest of World**</td>
<td>4,000 m</td>
<td>~2.5 x 10^{-2}</td>
<td>100,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>~430,000</td>
</tr>
<tr>
<td>estimated deaths</td>
<td></td>
<td></td>
<td>~43,000</td>
</tr>
</tbody>
</table>
## Updated doses from UNSCEAR 2008

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery operation workers</td>
<td>530</td>
<td>117</td>
<td>61 200</td>
</tr>
<tr>
<td>Evacuees</td>
<td>115</td>
<td>31</td>
<td>3 600</td>
</tr>
<tr>
<td>Inhabitants of contam areas of Belarus, Russia and Ukraine</td>
<td>6 400</td>
<td>-</td>
<td>58 900</td>
</tr>
<tr>
<td>Inhabitants of Belarus, Russian Federation and Ukraine</td>
<td>98 000</td>
<td>1.3</td>
<td>125 000</td>
</tr>
<tr>
<td>Inhabitants of W Europe</td>
<td>500 000</td>
<td>0.3</td>
<td>130 000</td>
</tr>
<tr>
<td>Total</td>
<td>380 000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
“Chernobyl's radioactive contamination >37 kBq/m² (1986-87) is responsible for 3.8 to 4.4% of overall mortality in areas of Russia, Ukraine, and Belarus. In other European countries with contamination levels around 19 kBq/m² (1986-87), the mortality is about 0.3 to 0.7%. Reasonable extrapolation for additional mortality in the heavily contaminated territories of Russia, Ukraine, and Belarus brings the estimated death toll to about 900,000 for the first 15 years after Chernobyl.”
Chernobyl: observed health effects

thyroid cancers
leukaemias
other solid cancers
non-cancer effects
minisatellite mutations
mental health + psychosocial
Thyroid Cancer Incidence
(in those who were children and adolescents in 1986) source: Jacob et al (2005)
Thyroid Cancer Incidence (2)


Incidence per 100,000 in Belarus

- Children (0 - 14)
- Adolescents (15 - 18)
- Adults (19 - 34)

Cases per 100,000:

How many excess thyroid cancers may occur?

- So far >6,000
- Cardis et al estimate 18,000 to 66,000 in Belarus alone
- assumes a constant relative risk over the whole of life
Thyroid cancer in other countries

Czech Republic
  - after 1990, incidence increased by 2.6% per year
  (95%-CI: 1.2-4.1) in all age categories

North England (greatest incidence in Cumbria)
- Cotterill et al (2001)
Leukaemia in Clean-up Workers

source: Ivanov (1997)
Leukaemia in Europe

Some reports of increased incidence of infant leukaemia

- not correlated with dose
- uncertainties in dose estimates
- European Childhood Leukaemia-Lymphoma Incidence Study (IARC)
- possible *in utero* effect
Solid cancers


- data from Belarus National Cancer Registry
- 40% increase in cancer incidence
## Solid Cancers

RR in cancer incidence (for ages 20-85 per 100,000 population) in Belarus liquidators 1997-2000, compared with control adults in least contaminated area (Vitebsk)

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Incidence in controls</th>
<th>Incidence in liquidators</th>
<th>RR</th>
<th>95% confidence intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sites</td>
<td>373.3</td>
<td>449.3</td>
<td>1.20*</td>
<td>1.14 – 1.27</td>
</tr>
<tr>
<td>Bladder</td>
<td>10.9</td>
<td>17.0</td>
<td>1.55*</td>
<td>1.21 – 1.99</td>
</tr>
<tr>
<td>Colon</td>
<td>17.0</td>
<td>22.3</td>
<td>1.31*</td>
<td>1.03 – 1.67</td>
</tr>
<tr>
<td>Lung</td>
<td>52.4</td>
<td>67.3</td>
<td>1.28*</td>
<td>1.13 – 1.46</td>
</tr>
<tr>
<td>Kidney</td>
<td>14.8</td>
<td>17.9</td>
<td>1.21</td>
<td>0.97 – 1.50</td>
</tr>
<tr>
<td>Stomach</td>
<td>41.7</td>
<td>44.9</td>
<td>1.08</td>
<td>0.92 – 1.26</td>
</tr>
<tr>
<td>Breast ♀</td>
<td>58.6</td>
<td>61.3</td>
<td>1.05</td>
<td>0.81 – 1.35</td>
</tr>
<tr>
<td>Rectum</td>
<td>19.0</td>
<td>18.4</td>
<td>0.97</td>
<td>0.77 – 1.23</td>
</tr>
</tbody>
</table>

source: Okeanov *et al* (2004) *statistically significant differences*
Breast Cancer

Recent ecologic study (Pukkala et al, 2006) of incidence in Belarus and Ukraine

- in most contaminated districts, average dose > 40 mSv
- relative risk in Belarus 2.2
- relative risk in Ukraine 1.8
Non-cancer effects in A-bomb survivors (Preston and Pierce, 2003)

<table>
<thead>
<tr>
<th>Condition</th>
<th>ERR/Sv</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>respiratory disease</td>
<td>0.18</td>
<td>0.06 to 0.32</td>
</tr>
<tr>
<td>heart disease</td>
<td>0.17</td>
<td>0.08 to 0.26</td>
</tr>
<tr>
<td>digestive disease</td>
<td>0.15</td>
<td>0.00 to 0.32</td>
</tr>
<tr>
<td>stroke</td>
<td>0.12</td>
<td>0.02 to 0.22</td>
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</table>
Non-cancer effects

Many reported effects (IAEA/WHO 2005) but evaluation is difficult:

- different diagnostic criteria
- insufficient control groups
- low statistical power
- confounding factors
Cardiovascular disease

- seen in A-Bomb survivors (Pierce et al, 2003) ERR/Sv = 0.17
- (Ivanov et al, 2000) study of Russian cleanup workers, ERR/Sv = 0.54 i.e. comparable to A-bomb survivors
Heritable Effects

- germline minisatellite mutation rates
- 2 x increase in groups from Belarus and Ukraine
- mutation induction in fathers not mothers
Collective dose and cancer deaths

- best global estimate = 600,000 person sieverts
- using risk factors of 5% and 10% per sievert
  = 30,000 – 60,000 predicted excess cancer deaths
- about 1/3 in Belarus, Ukraine and Russia, the rest in northern hemisphere, mostly in W Europe
- depends on the assumption of LNT
Displaced Persons (UNDP 2002)

Evacuated and resettled population

- Evacuated population:
  - Total: 24,000
  - Belarus: 24,000
  - Russia: 3,400
  - Ukraine: 111,000

- Resettled population:
  - Total: 118,400
  - Belarus: 49,000
  - Russia: 72,000

- Total:
  - Total: 231,000
  - Belarus: 52,400
  - Russia: 135,000
  - Ukraine: 163,000

- Yet to be resettled:
  - Total: 350,400
  - Belarus: 7,000
  - Russia: 4,600
  - Ukraine: 11,600
  - Total: 350,400
Epidemiology studies: care required

- differing diagnostic criteria used
- insufficient/poorly matched control groups
- small numbers – low statistical power
- confounding factors and biases
- nil or poor dose estimates

Only use reliable studies
Thyroid Cancer Incidence

Jacob et al (2005)
Leukemias in Clean-up Workers

Ivanov (1997)
## Solid Cancers


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<th>Cancer</th>
<th>Relative Risks</th>
<th>95% CIs</th>
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<tr>
<td>Breast</td>
<td>2.2</td>
<td>N/A</td>
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*RRs statistically significant at 95%
Cardiovascular Disease

Russian cleanup workers

ERR/Sv = 0.54 \ (Ivanov \ et\ al, \ 2000) \\

(is consistent with A-Bomb studies ERR/Sv = 0.17) \\
(Pierce \ et\ al, \ 2003)
Non-cancer effects in A-bomb survivors

(Preston and Pierce, 2003)

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<tr>
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all statistically significant at 95% level
Transgeneration Effects

- DNA minisatellite mutation incidence doubled in Belarus and Ukraine
- mutations in fathers not mothers
- passed to their children
Chernobyl: conclusions

- terrible consequences
- health effects still occurring
- different health effects appearing
- need more research + funding
- need to question denials by many governments
# Uncertainties in Dose Coefficients


<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Intake</th>
<th>Organ</th>
<th>( U ) Range = (ratio of 95(^{\text{th}})/5(^{\text{th}}) percentiles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>ingestion</td>
<td>red bone marrow</td>
<td>4</td>
</tr>
<tr>
<td>I-131</td>
<td>inhalation</td>
<td>thyroid</td>
<td>9</td>
</tr>
<tr>
<td>Sr-90</td>
<td>ingestion</td>
<td>red bone marrow</td>
<td>240</td>
</tr>
<tr>
<td>Pu-239</td>
<td>ingestion</td>
<td>red bone marrow</td>
<td>1,300</td>
</tr>
<tr>
<td>Sr-90</td>
<td>inhalation</td>
<td>lungs</td>
<td>5,300</td>
</tr>
<tr>
<td>Ce-144</td>
<td>inhalation</td>
<td>red bone marrow</td>
<td>8,500</td>
</tr>
<tr>
<td>Pu-239</td>
<td>ingestion</td>
<td>bone surface</td>
<td>20,000</td>
</tr>
</tbody>
</table>
References

• Cardis E (2005) Cancer effects of the Chernobyl accident (presentation at IAEA/WHO Conference 'Environmental and Health Consequences of the Chernobyl Accident')
• IAEA/WHO/EC (1996) One Decade After Chernobyl: Summing up the Consequences of the Accident.
• Jacob P, Meckbach R, Ulanovski A, Schotola C and Pröhl G (2005) Thyroid exposure of Belarusian and Ukrainian children due to the Chernobyl accident and resulting thyroid cancer risk. GSF-Bericht 01/05, Neuherberg: GSF-Forschungszentrum mbH, 725; mit Anhang
Reading List

**Books**

**Articles**