Biodosimetry of Plutonium Workers

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“Learning from Plutonium and Uranium Workers”
Sixteen Papers Reviewed

- Mayak (6)
- Sellafield (4)
- Rocky Flats (2)
- Manhattan Project – UPPU (1)
- UKAEA (1)
- Semipalatinsk (1)
- Russian Nuclear Workers (1)
Early Papers

• G.W. Dolphin (1971)
  ▪ 8 plutonium workers, who were exposed to:
    – Plutonium for 7 years, and
    – 14 rem external dose (average values).
  ▪ Pu workers were compared to unexposed controls and externally exposed workers from Buckton et al.
  ▪ Findings: any increase in dicentrics was attributed to external dose.

• Hemplemann et al. (1973) studied 25 UPPU club members (Manhattan project).
  ▪ No excess chromosome aberrations was found.
Types of Assays

• Solid Stained
• G-banding
• FISH (fluorescence in situ hybridization)
• mFISH
• mBAND
Asymmetrical Aberrations

<table>
<thead>
<tr>
<th></th>
<th>Was an excess observed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acentrics</td>
<td>Y - Livingston (2008, FISH)</td>
</tr>
<tr>
<td>Rings</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) External dose not accounted for.

A significant excess of asymmetrical aberrations would imply that mature lymphocytes are being irradiated by deposited plutonium.
## Symmetrical Aberrations

<table>
<thead>
<tr>
<th></th>
<th>Was an excess observed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetrical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y - Tawn (1985, G-bandng)</td>
</tr>
<tr>
<td></td>
<td>Y - Whitehouse (1998, G-bandng)</td>
</tr>
<tr>
<td>Stable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y - Okladnikova (2005, Romanovsky-Gimsa stain)</td>
</tr>
<tr>
<td></td>
<td>N - Tawn (2006, FISH)</td>
</tr>
<tr>
<td>Translocations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Y - Livingston (2008, FISH)</td>
</tr>
<tr>
<td></td>
<td>N - Salissidis (1998, FISH)</td>
</tr>
<tr>
<td></td>
<td>N - Tawn (2006, FISH)</td>
</tr>
</tbody>
</table>
Handling External Dose

• Significant external doses in most Pu-exposed workers
  ▪ Median: 290 mSv  Max: 3,300 mSv

• Most common: “external only” vs. “Pu + external”
  ▪ Ideally, each group had the same level of external dose
  ▪ Sometimes the “Pu + external” group had a higher external dose.

• Linear Regression
  ▪ Regress the number of chromosome aberrations against body burden, red bone marrow dose, and/or external dose.
Regression Results

<table>
<thead>
<tr>
<th>Study</th>
<th>External Dose</th>
<th>Body Burden (BB)</th>
<th>Red Bone Marrow (RBM)</th>
<th>Average Pu BB (kBq)</th>
<th>Average Pu RBM Dose</th>
<th>Average External Dose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salissidis et al. (1998)</td>
<td>Y</td>
<td>N</td>
<td></td>
<td>9.1$^a$</td>
<td></td>
<td>3,300 mSv</td>
<td></td>
</tr>
<tr>
<td>Burak et al. (2001)</td>
<td>Y</td>
<td>N</td>
<td></td>
<td>2.0</td>
<td></td>
<td>3,400 mGy</td>
<td></td>
</tr>
<tr>
<td>Livingston et al. (2006)</td>
<td>N</td>
<td>Y</td>
<td></td>
<td>168 mSv$^b$</td>
<td>280 mSv$^b$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okladnikova et al. (2005)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>7.99</td>
<td></td>
<td>90 mGy</td>
<td>External correlation not found for stable aberrations.</td>
</tr>
<tr>
<td>Sotnik et al. (2011)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>2.05</td>
<td>120 mGy</td>
<td>1,000 mGy WB mGy RBM</td>
<td>External correlation not found for intra-chromosomal aberrations.</td>
</tr>
</tbody>
</table>

$^a$ midpoint of range
$^b$ median

Note: Body burden and dose data are for the plutonium-exposed group (1-3) or the most highly exposed plutonium group (4-5)
Correcting for External Dose

• One study subtracted off the contribution from external dose (Tawn et al., 1985)
  ▪ Asymmetrical aberrations
  ▪ Assumed a 3-year half-life
  ▪ The number of expected aberrations from annual external doses were estimated, and subtracted from the total number of aberrations.

• Results: An increase in aberrations with increasing plutonium deposition was observed.

• Subsequent studies by similar authors do not find an increase in asymmetrical aberrations.
Intra-chromosomal Aberrations

• Several papers indicate that intra-chromosomal aberrations are a biomarker for past exposure to densely ionizing radiation.
  ▪ Mayak Worker Studies
    – Hande et al. (2003, mBAND/mFISH)
    – Mitchell et al. (2004, mBAND/mFISH)
    – Sotnik et al. (2011, mBAND/mFISH)
Conclusions

• Several studies have associated excess chromosome aberrations with incorporated plutonium.
• However, significant external radiation doses make it difficult to interpret these findings.
References


• Okladnikova ND, Scott BR, Tokarskaya ZB, Zhuntova GV, Khokhryakov VF, Syrchikov VA, Grigoryeva ES. Chromosomal aberrations in lymphocytes of peripheral blood among Mayak facility workers who inhaled insoluble forms of 239Pu. Radiat Prot Dosim 113: 3-13; 2005.

References

• Sotnik NV, Azizova TV Osovets SV. [Structural genomic damages in workers of plutonium production]. Radiats Biol Radioecol 51: 213-217; 2011. [In Russian]


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