METHODS OF ASSESSING PAST EXTERNAL EXPOSURES FROM ENVIRONMENTAL CONTAMINATION OF THE TECHA RIVER IN THE FORMER U.S.S.R.

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Previous External Dosimetry Studies

- EPA Federal Guidance Report No. 12 (FGR 12); 1993
  - Radionuclide-specific dose coefficients
    - ICRP 38 decay schemes
  - Adult stylized hermaphroditic phantom
  - Method for external dose coefficients

- Techa River Dosimetry System (TRDS); 2000 – Present
  - EPA FGR 12 organ dose coefficients
  - Adult stylized data only
Techa River Population Exposure

• Located southern Ural region, just east of Ural Mountains

• Result of failures in Mayak plutonium facility from ~ 1949 – 1956

• Exposure pathways
  • River drinking water
  • External gamma exposure

• Noted increase in both leukemia and solid cancer
  • Potential for direct data in general population (ETRC)
  • Potential for direct data in progeny (TROC)
Project Overview

• Noted increase in both leukemia and solid cancer
  • Potential for direct data in general population (ETRC)
  • Potential for direct data in progeny (TROC)

• Future TRDS – Techa River specific organ dose coefficients
  • Techa River soils
  • “Techa River phantoms”
  • Updated decay schemes – ICRP 107 vs. ICRP 38

• End goal: More accurate dose coefficients → More accurate dose reconstruction
Phantoms Utilized

• 1 YO, 5 YO, 10 YO, 15 YO, and adult male/female phantoms
  • UF/ICRP reference hybrid phantoms
  • ORNL stylized phantoms
  • UF Asian-scaled hybrid phantoms

• Asian-scaled phantoms matched according to height and sitting height and scaled using Rhinoceros 5®
  • Standing height
  • Sitting height
  • Chest circumference
Enamel/Dentin Delineation
Modeling Exposures

• 25 source energies
  • 10 keV – 10 MeV

• Infinite isotropic plane sources
  • 0, 0.04, 0.2, 1.0, 2.5, 4.0 mean free path depth

• FGR 12 dose coefficients for soil exposure
  • \( \rho_{\text{soil}} = 1.6 \text{ g cm}^{-3} \), Techa River specific?

• Three soils densities utilized
  • Reference (REF) = 1.6 g cm\(^{-3}\)
  • Upper Techa River (UTR) = 1.0 g cm\(^{-3}\)
  • Middle/Lower Techa River (MLTR) = 1.5 g cm\(^{-3}\)
Radiation Transport to Organ Dose Method

- Step 1: Transport to coupling cylinder
  - Environmental simulation to SSW file
Environmental Simulation
Radiation Transport to Organ Dose Method

- Step 1: Transport to coupling cylinder
  - Environmental simulation to SSW file

- Step 2: Re-transport from SSW to phantom
  - Read SSW file using SSR function in MCNPX
Radiation Transport to Organ Dose Method

- **Step 1: Transport to coupling cylinder**
  - Environmental simulation to SSW file

- **Step 2: Re-transport from SSW to phantom**
  - Read SSW file using SSR function in MCNPX

- **Step 3: Evaluate monoenergetic organ dose coefficients**

- **Step 4: Spectrum-weight monoenergetic organ dose coefficients**
  - $^{137}$Cs/$^{137m}$Ba, $^{106}$Ru/$^{106}$Rh, $^{144}$Ce/$^{144}$Pr, $^{95}$Zr, $^{95}$Nb, $^{91}$Y

- **Issues**
  - Hard drive space
  - Simulation time
Monoenergetic Photons – Liver: 0 – 2 cm

Energy (MeV)

Organ Dose Conversion Factor (Gy m$^3$ Bq$^{-1}$ s$^{-1}$)

UF_30M
UF_30F
FGR12 (1993)
Monoenergetic Photons: 0 – 2 cm
Inter-Soil Spectrum-Weighted Dose Coefficients

<table>
<thead>
<tr>
<th>Source Location (cm)</th>
<th>Max. % Diff. UTR to Reference Soil</th>
<th>Min. % Diff. UTR to Reference Soil</th>
<th>Max. % Diff. MLTR to Reference Soil</th>
<th>Min. % Diff. MLTR to Reference Soil</th>
<th>Max. % Diff. UTR to MLTR</th>
<th>Min. % Diff. UTR to MLTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>16.9%</td>
<td>10.4%</td>
<td>8.5%</td>
<td>1.8%</td>
<td>9.2%</td>
<td>7.4%</td>
</tr>
<tr>
<td>2-4</td>
<td>36.7%</td>
<td>22.1%</td>
<td>20.4%</td>
<td>1.1%</td>
<td>21.4%</td>
<td>11.6%</td>
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<tr>
<td>4-6</td>
<td>59.0%</td>
<td>41.3%</td>
<td>19.9%</td>
<td>0.2%</td>
<td>42.8%</td>
<td>24.3%</td>
</tr>
<tr>
<td>6-8</td>
<td>72.4%</td>
<td>53.4%</td>
<td>19.1%</td>
<td>-2.5%</td>
<td>64.8%</td>
<td>37.2%</td>
</tr>
</tbody>
</table>
Stylized/Asian-scaled vs. Reference: 0 – 2 cm
Reference Male Series: 0 – 2 cm

![Bar chart showing organ comparisons with different colors representing different data sets](chart.png)
## Reference Hybrid Phantoms vs. FGR 12

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<tbody>
<tr>
<td>01M</td>
<td>32.9%</td>
<td>-19.8%</td>
<td>18.4%</td>
<td>46.3%</td>
<td>7.6%</td>
<td>32.5%</td>
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<tr>
<td>05M</td>
<td>25.1%</td>
<td>-14.6%</td>
<td>12.9%</td>
<td>40.0%</td>
<td>9.4%</td>
<td>26.1%</td>
</tr>
<tr>
<td>10M</td>
<td>15.0%</td>
<td>-18.4%</td>
<td>7.0%</td>
<td>25.8%</td>
<td>5.9%</td>
<td>17.0%</td>
</tr>
<tr>
<td>15M</td>
<td>6.0%</td>
<td>-22.5%</td>
<td>0.2%</td>
<td>14.2%</td>
<td>2.0%</td>
<td>7.5%</td>
</tr>
<tr>
<td>30M</td>
<td>-1.0%</td>
<td>-25.4%</td>
<td>-8.6%</td>
<td></td>
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</table>
Conclusions

• Increasing the phantom age results in decreased organ dose coefficient

• UTR soil yields highest organ dose coefficients, followed by MLTR soil and FGR 12 soil

• Maximum absolute percent difference hybrid reference adult to stylized adult
  • 10% (male), 8.4% (female)

• Absolute maximum percent difference Asian-scaled male/female vs. reference male/female
  • 15.7% (adult male), 8.9% (5 YO female)
Conclusions

- Percent difference UTR $\rightarrow$ REF soil for adult male
  - 10.4% - 72.4% (over all source locations)

- Percent difference MLTR $\rightarrow$ REF soil for adult male
  - -2.5% - 20.4% (over all source locations)

- Percent difference UTR $\rightarrow$ MLTR soil for adult male
  - 7.4% to 64.8% (over all source locations)

- Overall...
  - Wide variation in dose coefficient dependent on soil, age, morphometry
  - Single stylized phantom does not accurately convey organ dose coefficient
  - Study underscores need for accurate quantification of organ dose coefficients from external sources
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