Savannah River Site (SRS) Special Exposure Cohort Petition Evaluation Report Addendum #3 – Thorium (post 1972)

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Knoxville, TN
Petition Overview

- November 2007: Petition received
- December 2008: Evaluation Report presented to the Advisory Board
- May 2010: Evaluation Report Addendum #1 – Thorium presented to SRS Work Group
- January 2011: Work Group/Sanford Cohen & Associates comments received
  - Significant Work Group finding: Potential thorium work in other areas not discussed in the Evaluation Report Addendum
Petition Overview—cont.

- February 2011: SRS status update presented to the Advisory Board

- August 2011: In SRS Addendum #2, NIOSH recommended adding a class of thorium exposed workers in the 773-A and TNX to the SEC from January 1953 to October 1972 and proposed identifying the class based on dosimeter badge location

- August 2011: NIOSH indicated more research was needed for the post-Oct 1972 time period
Petition Overview—cont.

- December 2011: Advisory Board partially concurred with NIOSH recommendation; however, recommended expansion of the class to include all workers at SRS

- March 2012: HHS Secretary added a class of all workers at SRS from January 1953 to October 1972 to the SEC

- November 2012: NIOSH issued third addendum to the SEC petition evaluation report regarding thorium (to cover the time period October 1972 through December 2007)
Recommendation to the Advisory Board

NIOSH believes reconstruction of thorium exposures is feasible and that doses can be reconstructed with sufficient accuracy for compensation purposes from October 1972 through December 2007.

How NIOSH reached this conclusion:

- Very low inventory (source term)
- Minimal use in certain defined locations
- Knowledge of the processes
- Radiological controls
- Alternate bioassay data
Thorium Inventory
(Presented in August 2011—Addendum #2)
Inventories indicate some small thorium work in later years.
Additional NIOSH Research

- **Reviewed**
  - Inventory reports (1972-2007)
  - SRL and Works monthly technical reports
  - Radiological surveys

- **Evaluated**
  - Whole body count data
  - Other bioassay methods

- **Learned**
  - Large spike of thorium work in 1977 that was reported in August 2011 was the receipt of spent thorium fuel in the receiving basin for offsite fuels (Receiving Basin for Offsite Fuels - RBOF)
Receiving Basin for Offsite Fuels (RBOF)

- Encapsulated spent nuclear fuels
- Fuels repackaged underwater
- Fuels stored underwater

After Additional Review of Records

Thorium Inventory (kilograms)

Year

Thorium Inventory
w/o water stored, encapsulated spent fuel

Year

Thorium Inventory without stored spent fuel (kilograms)

0  20000  40000  60000  80000  100000  120000
Inventories indicate very small thorium inventory 1972 - 2007
Most of the thorium inventory was waste and storage.

Less than 1% of the thorium on site was available for potential exposure.

**Thorium at SRS, 1993**

- 99% Waste/storage
- 1% Research
## Minimal Locations

### Table 5-2: SRS Thorium Inventory, 1972-2007 (kg) (partial)

<table>
<thead>
<tr>
<th>Year</th>
<th>773A</th>
<th>723A</th>
<th>235-F</th>
<th>772-F Lab</th>
<th>M Area</th>
<th>777 M</th>
<th>217-A Storage</th>
<th>100-K Basin</th>
<th>100-L Basin</th>
<th>RBOF</th>
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</thead>
<tbody>
<tr>
<td>1973</td>
<td>154.0¹</td>
<td>---²</td>
<td>0.0³</td>
<td>---</td>
<td>57.2</td>
<td>6.4</td>
<td>0.0³</td>
<td>52.0</td>
<td>---</td>
<td>6679¹</td>
</tr>
<tr>
<td>1974</td>
<td>104.0</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>52.0</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>104.0</td>
<td>0.5</td>
<td>1.1</td>
<td>1.1</td>
<td>43.2</td>
<td>5.4</td>
<td>---</td>
<td>52.0</td>
<td>---</td>
<td>6757</td>
</tr>
<tr>
<td>1976</td>
<td>89.4</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
<td>40.7</td>
<td>2.0</td>
<td>0.0</td>
<td>52.0</td>
<td>---</td>
<td>6757</td>
</tr>
<tr>
<td>1977</td>
<td>85.4</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
<td>25.4</td>
<td>2.0</td>
<td>0.0</td>
<td>52.0</td>
<td>---</td>
<td>8329</td>
</tr>
<tr>
<td>1978</td>
<td>56.6</td>
<td>---</td>
<td>4.0</td>
<td>4.0</td>
<td>25.2</td>
<td>2.1</td>
<td>0.0</td>
<td>52.0</td>
<td>---</td>
<td>8729</td>
</tr>
<tr>
<td>1979</td>
<td>83.4</td>
<td>---</td>
<td>4.0</td>
<td>4.0</td>
<td>31.1</td>
<td>2.1</td>
<td>0.0</td>
<td>52.0</td>
<td>---</td>
<td>8729</td>
</tr>
<tr>
<td>1980</td>
<td>108.6</td>
<td>---</td>
<td>4.5</td>
<td>4.5</td>
<td>31.1</td>
<td>---</td>
<td>8.0</td>
<td>52.0</td>
<td>3.1</td>
<td>8726</td>
</tr>
</tbody>
</table>
Minimal Locations—cont.

<table>
<thead>
<tr>
<th>Year</th>
<th>Thorium Inventory without stored spent fuel (kilograms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>200</td>
</tr>
<tr>
<td>2000</td>
<td>600</td>
</tr>
<tr>
<td>2010</td>
<td>1000</td>
</tr>
</tbody>
</table>

- **All non-storage areas**
- **773-A**
Thorium Nitrate

- Use of thorium nitrate is common in chemistry labs
Process Knowledge
(Savannah River Laboratory 773A)

- 1972: Alpha Material Laboratory used thorium oxide as a surrogate for Pu-238 testing in glove boxes
- 1973: Gram quantities of thorium dioxide shards were used in 773A hot cells to test vapor deposition
- 1977-1980: Alternate Fuel Cycle Technology Program (AFCT) and Thorium Fuel Cycle Technology Program (TFCT)—several research projects
Multiple AFCT/TFCT studies

- Mechanical grinding of ThO$_2$ in high level caves
- Study on effects of heat treatment on thorium oxide
- Testing on conceptual THOREX flowsheets of Elk River fuel in high level caves
- Analysis of off gassing of spent thorium fuel (Elk River Fuel – high level caves)
- Hanford prepared (encapsulated) 30 fuel rods with 80%ThO$_2$ – 20%UO$_2$ for irradiation at SRS. SRS received rods in 1979 and stored them in a cage in 773A. The program was cancelled in May 1980 before they could be irradiated.
Process Knowledge
(Other)

- **Pu-238 Fuel Form Facility (1980)**
  - Thorium used as a surrogate for some of the work performed in the hot cells of the PuFF. Also used as a doping agent of the iridium welding agents

- **Galileo Project (1987)**
  - Thorium used as a surrogate for plutonium during process testing

  - Thorium used as a surrogate for plutonium and other radionuclides to test methods for defense waste stabilization and immobilization
## Summary of Thorium Use

For more details please see Table 5-3

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation</th>
<th>Locations</th>
<th>Average Inventory (kg)</th>
<th>Activity (millicuries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-1975</td>
<td>Storage, Surrogate</td>
<td>773A, M Area (storage)</td>
<td>158</td>
<td>15.8</td>
</tr>
<tr>
<td>1976-1981</td>
<td>alternative fuels program, tritium studies, storage, surrogate</td>
<td>773A, 235-F, M Area (storage)</td>
<td>127</td>
<td>12.7</td>
</tr>
<tr>
<td>1982-1989</td>
<td>welding agent studies, storage, surrogate</td>
<td>773A, 235-F, M Area (storage)</td>
<td>38</td>
<td>3.8</td>
</tr>
<tr>
<td>1990-2003</td>
<td>defense waste research, storage, surrogate</td>
<td>773A, 235-F</td>
<td>224</td>
<td>22.4</td>
</tr>
<tr>
<td>2004-2007</td>
<td>defense waste research, storage, surrogate, D&amp;D</td>
<td>773A</td>
<td>5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Radiological Controls (1972-1990)

- DPSOP-40 Savannah River Plant Radiation and Contamination Control and DPST-RH Radiation Hazards Technical Standards covered:
  1. Work in regulated areas
  2. Investigating radiation and contamination incidents
  3. Protective clothing
  4. Injury in regulated areas
  5. Disposal of contaminated waste
  6. Fires in regulated areas
  7. Radiation exposure control
  8. Internal radiation exposure control
Radiological Controls (1991-2007)

- SRS implemented a new radiation control manual (WSRC-5Q) in 1991 to comply with DOE Order 5480.11, it was updated as follows to comply with:
  - 1992 DOE Radiological Control Manual DOE N 5480.6
  - 1994 DOE Radiological Control Manual DOE/EH-0256T
  - 1995 Occupational Radiation Protection 10CFR835
Other Radiological Information

- NIOSH has collected samples of contamination surveys in 773-A, M Area, 235-F, and TNX from 1972 through 1988
- NIOSH has collected samples of air monitoring surveys from 773-A, 235F, and 244-F from 1972 through 1988
- More contamination surveys and air sample results are available in electronic form
Radionuclide Activities (1994)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Inventory (g)</th>
<th>SA (Ci/g)</th>
<th>Activity (Ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Th-232</td>
<td>4.12E+07</td>
<td>1.10E-07</td>
<td>4.5</td>
</tr>
<tr>
<td>Np-237</td>
<td>6.90E+04</td>
<td>6.90E-04</td>
<td>47.6</td>
</tr>
<tr>
<td>U-233</td>
<td>1.34E+04</td>
<td>9.50E-03</td>
<td>126.8</td>
</tr>
<tr>
<td>Cf-252</td>
<td>2.50E-01</td>
<td>5.40E+02</td>
<td>135.1</td>
</tr>
<tr>
<td>Pu-239</td>
<td>5.13E+05</td>
<td>6.20E-02</td>
<td>31806.0</td>
</tr>
<tr>
<td>Am-241</td>
<td>7.23E+04</td>
<td>3.20E+00</td>
<td>231360.0</td>
</tr>
<tr>
<td>Cm-244</td>
<td>1.12E+04</td>
<td>8.20E+01</td>
<td>915940.0</td>
</tr>
<tr>
<td>Pu-238</td>
<td>1.49E+05</td>
<td>1.70E+01</td>
<td>2533000.0</td>
</tr>
</tbody>
</table>

Table includes waste that is not available for intake; in 1994 only 0.0176 Ci were non-waste.
Alternate Bioassay Data

- A large number of workers in 773-A were monitored for Am, Cm, and Cf.

- Review of the bioassay method during development of the co-worker model for Am, Cm, and Cf revealed that thorium would come through in the analysis and the alpha emissions would be counted as if it were Am, Cf, or Cm.

“A procedure was developed for sequential extraction of plutonium, neptunium, and uranium with tri-isoctylamine (TIOA), followed by extraction of thorium, americium, curium, berkelium, californium, and einsteinium with bidentate. Compared with previous methods, the new procedure is simpler, requires less analysis time, and gives better recovery. The recovery of Am-Cm-Cf from 250 ml of urine or 20 grams of feces was 90%.”
“All alpha emitting actinides from thorium through einsteinium extract, indicating an excellent gross alpha analytical procedure. The data show that in analysis of americium, curium, and californium any contaminating plutonium, neptunium, or uranium must be removed. At this laboratory, thorium, berkelium, and einsteinium are not present in biological samples in sufficient quantities to require separation or routine identification by alpha spectrometry.”
Thorium Volume and Activity

- **Mass**
  - 200 kg = 20.0 mCi

- **Small volume**
  - 200 kg = approximately ten 2L bottles of ThO₂

- **773-A is a fairly large building**
  - Small volumetric source term
Alternate Bioassay Data

- No effort was made by the lab to remove the thorium contaminant from the urine sample

Why
- Activities were much lower
- Not viewed as a significant contaminant
- Thorium used as a surrogate because it was less hazardous than plutonium (i.e. safer to use)

Effectively we have alpha urine bioassay sample that does not contain plutonium, uranium, or neptunium, but does contain Th, Am, Cm, Cf, Es, and Bk
How high are the doses (1972-1994)?

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Lung Dose (rem)</th>
<th>Bone Dose (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type M</td>
<td>2.60</td>
<td>18.66</td>
</tr>
<tr>
<td>Type S</td>
<td>79.92</td>
<td>23.34</td>
</tr>
</tbody>
</table>
Whole Body Count Data

- In 1995, SRS started using Alpha Spectrometry (not gross alpha counts)
- Thorium was not one of the alpha energies evaluated
- Am, Cm, and Cf analysis only valid from 1972-1994
- Must use Whole Body Count Data
  - MDA for Th-232 = 0.15 nCi
### Estimated Organ Dose from Thorium (1995-2007)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Lung Dose (rem)</th>
<th>Bone Dose (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type M</td>
<td>56.94</td>
<td>174.3</td>
</tr>
<tr>
<td>Type S</td>
<td>15.40</td>
<td>1.75</td>
</tr>
</tbody>
</table>

During the Radiological Controls from 10CFR835
Whole Body Count Data

- NIOSH has concluded that by this time period under 10 C.F.R. 835, people who should have been monitored were monitored.

- NIOSH has also obtained lapel air sample data from 2004 when remediation work was conducted on a concrete pad that was contaminated with thorium.
Summary

- Very low inventory (source-term)
  - More thorium inventory in 1990s and 2000s than 1970s and 1980s
  - Most thorium on site was waste/storage

- Minimal use in certain defined locations
  - Mostly 773-A (especially post-1983)

- Knowledge of the processes
  - Mostly used as a surrogate
  - Except for AFCT/TFCT (1977-1980)
Radiological controls
- Procedures in place
- Routine monitoring of the workplace
- Survey data available
- Air monitoring data available

Alternate bioassay data
- Am, Cm, and Cf bioassay was effectively gross alpha analysis that included thorium
- Doses are plausible
# Feasibility Summary

## Feasibility Findings for Savannah River Site 1972-2007

<table>
<thead>
<tr>
<th>Source of Exposure</th>
<th>Dose Reconstruction Feasible</th>
<th>Dose Reconstruction NOT Feasible</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Thorium</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Recommendation

- For the period October 1, 1972 through December 31, 2007, NIOSH finds that radiation dose from exposure to thorium can be reconstructed for compensation purposes.

<table>
<thead>
<tr>
<th>Class</th>
<th>Feasibility</th>
<th>Health Endangerment</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 1, 1972 – December 31, 2007</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>