SC&A Review of Proposed NIOSH Methods for Reconstructing Thorium Doses at Fernald (1979–2006)

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Thorium Internal Dose Reconstruction at Fernald

- Two separate SEC periods were granted for Fernald on the basis of the inability to reconstruct internal thorium exposures
  - 1968–1978 recommended by ABRWH on 5/29/2012
  - 1953–1967 recommended by ABRWH on 8/28/2013
- 6/26/2014: NIOSH releases a white paper detailing dose reconstruction methods from 1/1/1979 through 12/31/2006

Summary of Proposed Dose Reconstruction Methods (1979–2006)

- DR methods can be split into three distinct periods: 1979–1989, 1990–1994, and 1995–2006
- Three periods delineated by the monitoring methods employed, data availability, and monitoring coverage in each time period
- Table on pages 12 and 13 of NIOSH white paper summarizes the methods for each period

Summary of Proposed Dose Reconstruction Methods (1979–2006) continued

Timeframe	In Vivo Data Exists (Yes/No)	Evaluation Method
1979–1994	Yes	In Vivo Results
1979–1989	No	Coworker Data
1990–1994	No	10% Th-232 Class W DAC
1995–2006	Yes - may use to decide if in vivo results reflect a lung burden that had been previously identified from earlier exposure. Positive in vivo is used in place of negative BZ results unless it is an artifact of an earlier detected lung burden. For in vivo results below MDA use BZ results. No – use BZ data	BZ Air Monitoring results

Summary of Proposed Dose Reconstruction Methods (1979–2006) continued

- **Selection of "thorium workers" during initial period (1979–1989)**
  - **NIOSH white paper indicates the following job types: chemical operators, fork truck drivers, laborers, transportation laborers, operations, production workers, maintenance personnel**
  - **Discussion during 9/3/2014 WG, Mr. Hinnefeld:** ***"And we'd be pretty encompassing about that. You figure almost anybody in operations could have done that, most anybody in maintenance. Transportation could have been involved in it. You have safety and health people. Might have security people there. So you've got to be pretty inclusive…"***

Summary of Proposed Dose Reconstruction Methods (1979–2006) continued

- Selection of unmonitored "thorium workers" during initial period (1990–1994)
  - Summary Table from NIOSH white paper who will be assigned thorium doses based on 10% of the DAC
  - Main text of the whitepaper states: *"1990–1994: Thorium workers with no in vivo results, but with pre-job fecal sample results during this employment period at Fernald are recommended to be assigned a dose…"*
- Unmonitored workers from 1995–2006 are not assigned a thorium coworker dose

Summary of Proposed Dose Reconstruction Methods (1979–2006) continued

- NIOSH white paper also provides methods for calculating thoron exposure to thorium-related activities

Time Period*	Area/Plant	WLM**/year
1977–1979	Pilot Plant	0.03
1972–1989	Storage facilities, repackaging, etc.	1.6
1972–2006	Closure Various Storage	0.5

Summary of Proposed Dose Reconstruction Methods (1979–2006) continued

- **White paper does not necessarily specify a specific worker or location that would restrict application of thoron exposures**

- **White paper states:** ***"The dates and bounding levels of calculated potential exposures represent recorded operational history. However, thorium was present on site for most of its history. For unknown work locations and time periods of concern, Dose Reconstructors should assume that thoron exposure potential existed, as a claimant-favorable assumption, and assign thoron doses based on the guidance from the table."***

Completeness Evaluation of Thorium In Vivo Records (1979–1989)

Year	# Samples
1979	177
1980	188
1981	141
1982	180
1983	169
1984	371
1985	382
1986	463
1987	562
1988	108
All In Vivo Data (1979–1988)	2741

Completeness Evaluation of Thorium In Vivo Records (1979–1989) continued

Job Title	# of Samples (% of Total)	Magnitude of Results (nCi)	
		95th Percentile (Ac-228)	95th Percentile (Pb-212)
Chemical Operator	1207 (55.0%)	0.387	0.330
Unknown	549 (25.0%)	0.150	0.160
Construction Trades	248 (11.3%)	0.096	0.056
Other Operator	156 (7.1%)	0.278	0.194
Millworker	141 (6.4%)	0.100	0.020
Engineer/Technician	81 (3.7%)	0.100	0.030
Supervisor	73 (3.3%)	0.186	0.200
Industrial Truck Operator ITO	68 (3.1%)	0.120	0.113
Laborer	59 (2.7%)	0.104	0.071
Inspection/QA	53 (2.4%)	0.084	0.050
Oiler/Degreaser	28 (1.3%)	0.097	0.070
Health and Safety	21 (1.0%)	0.090	0.260
Administrative	20 (0.9%)	0.061	0.057
Mechanic	16 (0.7%)	0.073	0.040
Security	12 (0.5%)	0.183	0.282
Laundry	10 (0.5%)	0.081	0.000

Completeness Evaluation of Thorium In Vivo Records (1979–1989) continued

Plant Area	# of Samples (% of Total)	Magnitude of Results (nCi)	
		95th Percentile Ac-228	95th Percentile Pb-212
Other Areas	1033 (37.7%)	0.150	0.170
Plant 5	650 (23.7%)	0.320	0.210
Plant 9	189 (6.9%)	0.146	0.086
Unknown	168 (6.1%)	0.157	0.167
Plant 6	156 (5.7%)	0.143	0.150
Plant 4	152 (5.5%)	0.230	0.180
Plant 1	111 (4.0%)	0.221	0.238
Pilot Plant	99 (3.6%)	0.355	0.305
Plant 2/3	94 (3.4%)	0.110	0.063
Plant 8	90 (3.3%)	0.136	0.121

Completeness Evaluation of Thorium In Vivo Records (1979–1989) continued

- SC&A evaluated the number of days that would elapse between a given worker's samples

Sample Type	Number of Days Elapsed to Next Sample		
	Arithmetic Average	Geometric Mean	Rank-Ordered Median
All Samples	463	331	377
Positive Samples	106	36	31
Samples Less than the MDA	479	364	384

Adequacy Evaluation and Interpretation of Thorium In Vivo Records (1979–1989)

- **Four main facets for interpreting the in vivo monitoring data:**
  1. **Assumption of triple-separated thorium**
  2. **Use of Pb-212 to calculate Th-232 and Th-228 intakes after results are adjusted for bias (median/mean of the normal analytical background adjusted to zero)**
  3. **Exposures to unsupported Ra-228 to the monitored and unmonitored worker**
  4. **Calculation of the OPOS Statistic**
     - **Use of Ac-228 chest burden results to assign Ra-228 intakes.**
     - **Evaluate the Ac-228 chest burden (MDA/2 for missed dose or the measured result adjusted for bias) with Ra-228 biokinetic model and assign it as intake rate of Type M Ra-228.**

Adequacy Evaluation and Interpretation of Thorium In Vivo Records (1979–1989) continued

1. Assumption of Triple-Separated Thorium
   - Discussed in numerous work group meetings, including the June 13, 2013 deliberations
   - SC&A 2012 had the following statement concerning triple separated thorium: *"SC&A agrees that the triple-separation hypothesis (Th-228/Th-232 = 0.19) is claimant favorable, for the period 1979–1988, when Pb-212 results are used to calculated the doses."*
   - SC&A's position remains unchanged

Adequacy Evaluation and Interpretation of Thorium In Vivo Records (1979–1989) continued

2. **Use of Pb-212 to calculate Th-232 and Th-228 intakes after a correction for bias:**
   - **SC&A 2012 had expressed concerns that there was an observed negative bias in the data: *"Most of the Th-232 progeny results above the MDA are for Ac-228, and in most cases, Ac-228 activities are higher than the Pb-212 activities in the lung."***
   - **Subsequently, NIOSH calculated an adjustment for the observed bias in the chest counts of Ac-228 and Pb-212.**
   - **SC&A agrees with the adjustments for bias calculated by NIOSH.**

Adequacy Evaluation and Interpretation of Thorium In Vivo Records (1979–1989) continued

3. Exposures to unsupported Ra-228:
   - SC&A agrees with the use of Ac-228 results to calculate intakes of Ra-228, as described by NIOSH for the monitored worker.
   - Evaluate the Ac-228 chest burden (MDA/2 for missed dose or the measured result adjusted for bias) with Ra-228 biokinetic model and assign it as an intake rate of Type M Ra-228.
   - NIOSH has not proposed a method for estimating unsupported Ra-228 exposures to the unmonitored worker.

Adequacy Evaluation and Interpretation of Thorium In Vivo Records (1979–1989) continued

4. **Calculation of the OPOS (one person – one sample) Statistic:**
   - **Thorium coworker model currently assumes a "post-weighted" OPOS approach**
   - **SC&A currently recommends a "pre-weighted" OPOS approach**
   - **Currently under discussion by the SEC Issues Work Group**
   - **Issue should be tabled pending the results of those discussions**

SC&A Analysis of Job Types Potentially Exposed to Thorium

- Page 16 of the NIOSH whitepaper provides a short list of job types considered thorium workers for the purposes of assigning coworker intakes (1979–1989):
  - Chemical Operator
  - Fork Truck Drivers
  - Laborers
  - Transportation Laborers
  - Operations
  - Production Workers
  - Maintenance Personnel

SC&A Analysis of Job Types Potentially Exposed to Thorium (continued)

- SC&A analyzed available claimant files (CATI, DOE Response, DOL Case Files) to determine the appropriateness of the list of job types
- SC&A only examined claims with a POC <50%
- Workers were classified into four categories of workers based on the current guidance
    1. Not likely to be assigned coworker intakes
    2. Likely to be assigned coworker intakes
    3. Unknown coworker applicability
    4. Ambiguous coworker applicability

SC&A Analysis of Job Types Potentially Exposed to Thorium (continued)

- The number of claims in each category is shown in the table below:

Job Type Category	Potential for Thorium Exposure	Number of Claims (% of Total)
1	Not likely	94 (24.5%)
2	Likely	108 (28.2%)
3	Unknown	25 (6.5%)
4	Potentially	156 (40.7%)

- Claims that fell into the third and fourth category are most germane to this investigation
- SC&A examined 20 such claimants in these categories

SC&A Analysis of Job Types Potentially Exposed to Thorium (continued)

- **Observations based on the examination of 20 non-compensated claims:**
  1. **Job categories included: engineers, fire protection, technicians, analytical chemists, supervisors, inventory control, clerks, laundry, and various types of trades workers.**
  2. **13 of 20 surveyed claims indicated exposure potential to thorium in the CATI report.**
  3. **Several claimants who worked after 1988 were monitored by the IVEC system, but were not monitored or sporadically monitored prior to this time.**
  4. **10 of the 20 claimants indicated that work locations were highly variable and they "worked all over the site."**
  5. **6 claimants specifically indicated direct work with thorium or in thorium areas (Building 64 and 65, thorium overpack, "thorium warehouse")**

Review of Coworker Assignments (1990–1994)

- Monitored worker doses based on the IVEC in vivo monitoring system
- Unmonitored worker thorium intakes are assigned based 10% of the class W thorium DAC value (5×10^{-13} µCi/ml)
- DAC value for solubility class Y is a factor of two higher (1×10^{-12} µCi/ml)
- NIOSH should consider the limiting DAC value based on solubility class Y unless information exists to the contrary

Review of Thorium Dose Assignments (1990–1994) continued

- Many workers were monitored via the IVEC system during this period
- SC&A examined the records of claimants who have a POC <50% and worked for at least 3 months in the period of interest
- 252 total claimants identified for examination

Review of Coworker Assignments (1990–1994) continued

- **Observations based on claimant review:**
  1. **Nearly 75% of the examined claims were monitored via the IVEC system**
  2. **67 claims were not monitored via the IVEC system in the 1990–1994 period**
  3. **45 of 67 can be considered job titles with little exposure potential including: clerk, secretary, contract administrator, HR representative, computer programmer, occupational health nurse, contract attorney, mail courier, intermittent auditor, estimator, data entry/analyst**

Review of Coworker Assignments (1990–1994) continued

- **Observations based on claimant review (cont):**
  4. The remaining claims (22 out of 67) may have had exposure potential including: laborers, maintenance, painters, iron workers, heavy equipment operators, technologist, quality assurance, health physics, and engineers.
  5. 9 of 22 unmonitored claims indicated “work all over the site”
  6. 11 of 22 unmonitored claims indicated exposure in radiological areas was intermittent or non-existent
  7. External badging was intermittent to non-existent in 10 of 22 cases
  8. One claim indicated involvement in thorium overpacking, however the operation likely occurred after 1994 based on available breathing zone data.

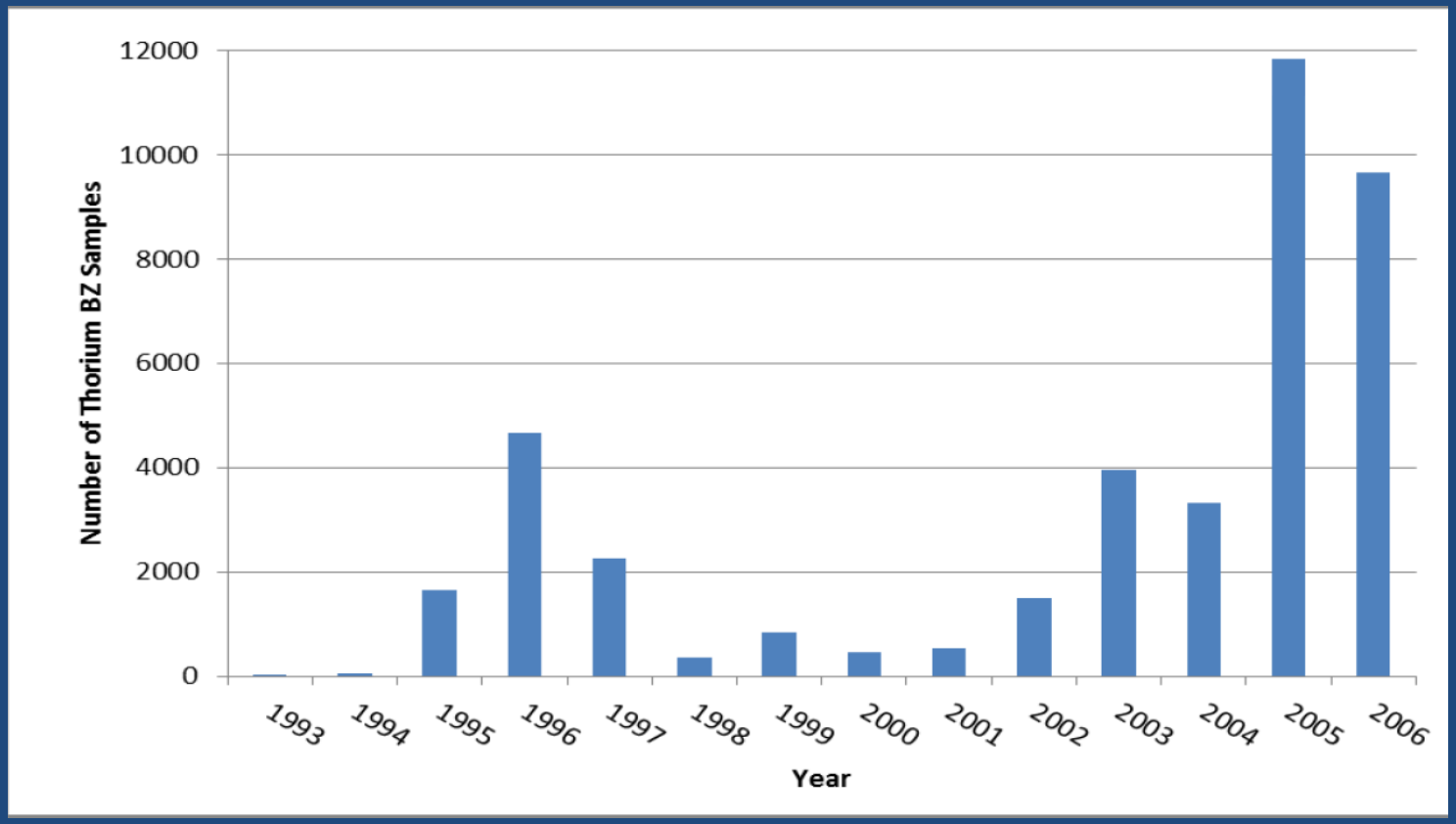
Review of Coworker Assignments (1990–1994) continued

- NIOSH white paper indicates that coworker intakes based on 10% of the DAC should be applied to workers who submitted thorium fecal samples but were not monitored via the IVEC system
- Based on sampling of unmonitored claimants, it is unlikely workers would have been chronically exposed at a level above 10% of the DAC for the duration of relevant employment
- Based on the sampling of unmonitored claimants, SC&A feels it is inappropriate to restrict coworker intakes based on the presence of a pre-employment fecal sample

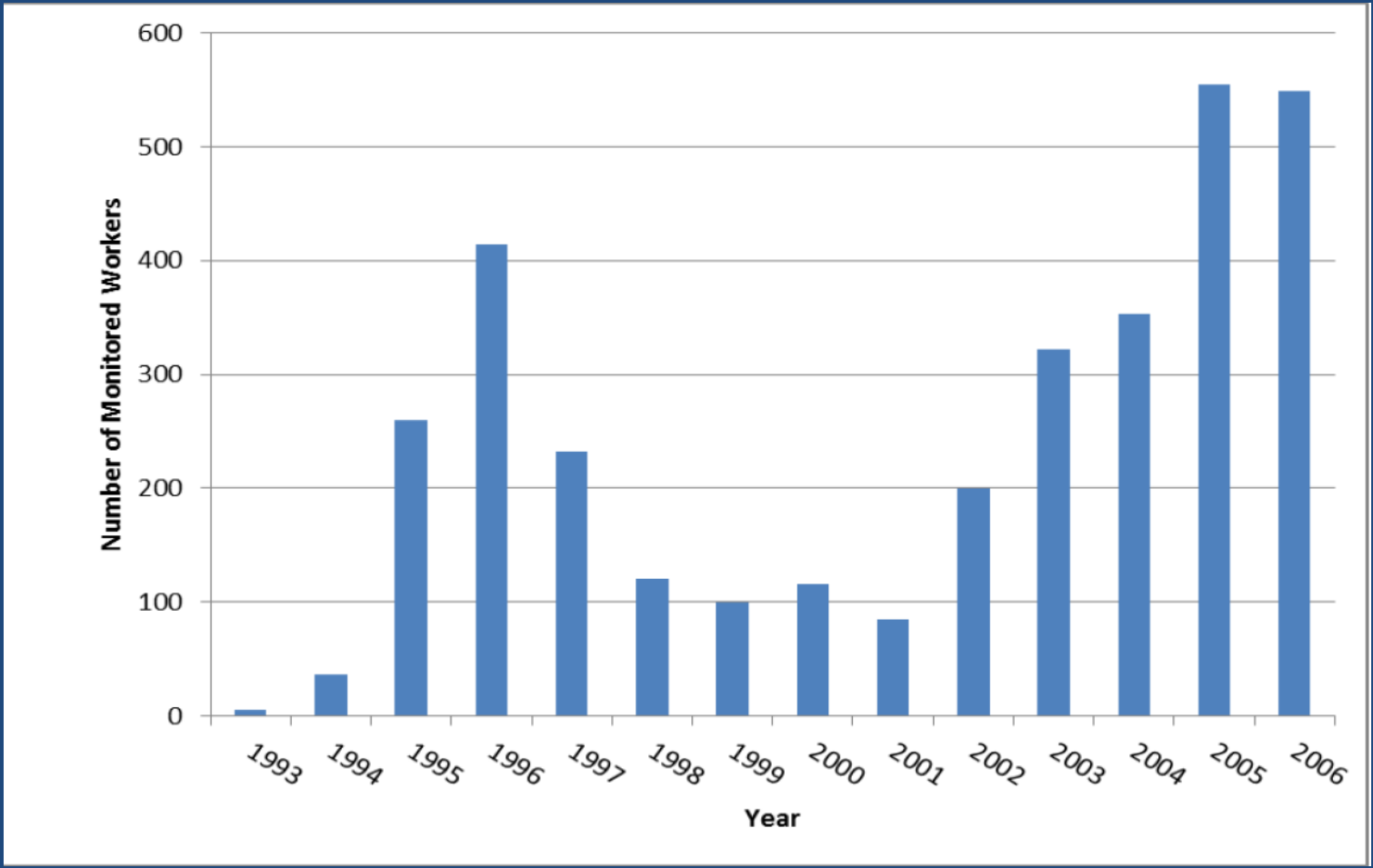
Analysis of Breathing Zone Data for Dose Reconstruction (1995–2006)

- Available breathing zone samples are used to reconstruct exposures to monitored workers
- No coworker dose assignment has been proposed after 1994
- Issue was discussed at 9/3/2014 work group: *"the thorium area would be defined… And if you're going into this, into the thorium radiological area or the airborne, potential airborne area, everybody had a BZ with them."* - Mr. Hinnefeld

Analysis of Breathing Zone Data for Dose Reconstruction (1995–2006) continued



Analysis of Breathing Zone Data for Dose Reconstruction (1995–2006) continued



Analysis of Breathing Zone Data for Dose Reconstruction (1995–2006) continued

- Example provided before of a claimant who stated they were involved in thorium overpack operations
- From CATI: *"*[redacted] *worked in the Thorium Overpack site where* [redacted] *remotely operated a device that would move drums around.* [Redacted] *had to dress out and enter the building to get an electric forklift, went over to the actual boxes they loaded the drums in (overpacks),* [redacted] *put a lid on the boxes and set them in an area for the Chemical Operators to clean, then the Rad Techs came in to survey them, if they were clean they were sent out to a driver on the "clean" area on process side and then they were sent to an area to be readied to ship offsite.* [Redacted] *... In the Thorium Overpack* [redacted] *had to wear double sets of cloth coveralls.* [Redacted] *had to wear a cloth hood...* [redacted] *always wore a full-face respirator in the Thorium Overpack area...* [redacted] *had lapel monitoring done when* [redacted] *was in Thorium Overpack when* [redacted] *was dressed out in double sets of anti-contamination clothing.*

Analysis of Breathing Zone Data for Dose Reconstruction (1995–2006) continued

- Numerous thorium BZ samples were identified for this claimant both in the claim file and the HIS_20
- BZ samples covered the assumed period in question and were pulled and measured approximately every 6–7 days

Review of Thoron Exposure Estimates

- **Major assumptions**
  1. **The white paper appears to contradict itself on the assumption of 300 mT thorium in the storage sites (the preceding page appears to quote 450 mT, the introduction quotes over 2000 mT of thorium materials in addition to the plant 8 silos and bins and pilot plant storage).**
  2. **The release fraction should be better established. Quoted release fractions in the white paper appear to range from 10^{-6} all the way to 10^{-3}.**
  3. **The equilibrium factor of 0.02 (or 2%) is not well founded. The stated reference indicates equilibrium factors could range from 2%–10%, but also notes "more precise studies are warranted."**

Review of Thoron Exposure Estimates (continued)

- **Major assumptions (continued)**
  4. **SC&A could not determine the rationale behind occupancy times of 3 months (up through 1989) and 1 month (during final closure).**
  5. **The specific activity of thoron was given as 6.4×10^{-4} pCi/g assuming exposures occurred 6–12 months after separation and an equilibrium fraction of Th-228/Th-232 of 0.65. The equilibrium fraction of materials stored in Building 65 was at least 0.95.**
- **NIOSH should evaluate potential exposure to thoron and progeny associated with storage and/or handling of Ra-228.**

Main Conclusions

- SC&A finds that dose reconstruction for internal thorium exposures is feasible and can be performed in a claimant-favorable manner from 1979 through 2006.
- For 1979–1994, claimants should only be restricted from application of coworker intakes if it is clearly demonstrable that no thorium/thoron exposure potential existed for the worker.
- The main parameters for estimating exposure to thoron should be better described and established to assure that thoron exposures are calculated in a scientifically defensible, claimant-favorable and/or bounding approach.

Questions?