ORAUT Responses to Fernald SC&A Clarifying Questions

Response Paper

National Institute for Occupational Safety and Health

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RECYCLED URANIUM

SC&A Clarifying Question 2: How was NIOSH able to determine which lots were processed prior to 1973 as was indicated in Figure 1 (above) as well as the most recent responses contained in NIOSH 2017b?

NIOSH's current approach in ORAUT-TKBS-0017-5, the Feed Materials Production Center – Occupational Internal Dose Technical Basis Document used the information found in the Ohio Field Office Report (SRDB Ref ID #3644). The FEMP Lot Marking and Color Coding System Requirements Manual Number RM-0005 (Pages 678-735 of SRDB Ref ID #3644) can be used to identify when a lot was processed. This is covered in Section 2.5 of the Ohio Field Office report (i.e. Lot or Sequence Number). This section indicates that one can determine the month of production for a given lot by converting the Sequence Number to a date. This is how NIOSH determined which lots in Attachment C were processed prior to 1973.

SC&A Clarifying Question 3: NIOSH 2011 indicates that for the period prior to 1973, Subgroup 6A (UO_3 from Hanford) was utilized in arriving at 10 Pu ppb, though it is not clear if this assumption is still being utilized. It is also not clear if the Subgroup 6A data was extrapolated backwards from post-1973 to the earlier period. If data is being back extrapolated, further discussion of the use of this later data as a substitute may be warranted.

NIOSH is no longer using the determination on the analysis performed in NIOSH 2011, Issues Related to the Ability to Bound Internal Dose from Recycled Uranium Trace Level Contaminants at Fernald, Draft 01. NIOSH's use of the 10 ppb Pu in recycled uranium (RU) through 1972 is based on the lot data found in Attachment C of the Ohio Field Office Report (SRDB Ref ID #3644). Based on a qualitative review of the lots identified as being processed prior to 1973, it appears that more than 95% of the identified Pu concentrations are below 1 ppb. Of those that are above 1 ppb Pu, most of those are still below 10 ppb Pu. This means that any potential to exposures to RU with Pu concentrations greater than 10 ppb would be considered rare and to be short in duration. The remaining, and thus, majority, of any worker's exposure time would have been associated with materials well below the recommended default level of 10 ppb Pu. Therefore, NIOSH cannot identify any reason to believe that any worker could have an exposure for which the recommended default level of 10 ppb Pu would not be adequately conservative and bounding.

SC&A Clarifying Question 4: What analytical basis was used to determine the potential contaminant ratios experienced by workers involved in the MgF process in the 1961-1972 period? Furthermore, what is the analytical basis used to conclude that workers exposed to the MgF source term would be sufficiently "averaged out" with exposures to other, less contaminated, recycled uranium?

Similar to the response for Clarifying Questions 3 above, NIOSH is no longer using the determination on the analysis performed in NIOSH 2011, Issues Related to the Ability to Bound Internal Dose from Recycled Uranium Trace Level Contaminants at Fernald, Draft 01. NIOSH's use of the 10 ppb Pu in RU through 1972 is based on the lot data found in Attachment C of the

Ohio Field Office Report (SRDB Ref ID #3644). Based on a qualitative review of the lots identified as being processed prior to 1973, it appears that more than 95% of the identified Pu concentrations are below 1 ppb. Of those that are above 1 ppb Pu, most of those are still below 10 ppb Pu. This means that any potential to exposures to RU with Pu concentrations greater than 10 ppb would be considered rare and to be short in duration. The remaining, and thus, majority, of any worker's exposure time would have been associated with materials well below the recommended default level of 10 ppb Pu. Therefore, NIOSH cannot identify any reason to believe that any worker could have an exposure for which the recommended default level of 10 ppb Pu would not be adequately conservative and bounding.

Additionally, some insight about "averaging out" the higher than typical TRU:U ratios in MgF can be obtained from a site expert interview, SRDB 38132. In lines 244 through 251 of that interview the expert relates that metal production (which generated the MgF) and metal fabrication generated residues that were sent back through the refinery to reclaim the enriched U. The total residues reclaimed in that fashion were about 3% to 5% of the enriched uranium produced. This means that over 90% of the enriched material processed in a year came from sources other than Fernald residues, so the TRU:U ratio found in MgF would be averaged out by the other sources.

THORON

SC&A Clarifying Question 5: What additional resources, references or documentation (if any) were consulted in determining that the originally assumed release fraction of 10-4 is the most appropriate?

A release fraction is inherently an empirical simplification of the process of emanation, diffusion, advection, absorption and adsorption, which were discussed by Rogers and Nielson in SRDB Ref ID #27376. With so many variables and no specific data available to individually quantify each one, empirical experience provides the best available basis for selection of the release fraction parameter. No other references or documentation for the selection of the value was used. As noted in the discussion above, the release fraction is expected to range from 10-3 to 10-4, (in other words, from 0.1% to 0.01%). When this value is assumed, the thoron exposure calculated in Clarifying Question 7 item #1 (below) matches well with the empirically observed thoron exposure shown in Clarifying Question 7 item #2 (below).

SC&A Clarifying Question 6: NIOSH 2017b indicates that the occupancy factor should remain at 25% (3 months per year) for the period from 1954 to 1989 but does not provide any additional justification or discussion. It is also not clear if the assumption of 1 month of exposure per year from 1990 to 2006 still applies. SC&A requests clarification as to how the currently assumed occupancy times were substantiated.

These occupancy factors are based on the assumption that storage facilities are not occupied full time as processing facilities would be. The occupancy factor could range from zero to 100%, both of which seem unlikely for a storage facility. In Building 65, the assumed value, along with the assumed release rate, resulted in a plausible agreement with a measured value. The 1 month of exposure per year from 1990 to 2006 assumption of exposure per year from 1990 to 2006 does not apply, since the three-month value in NIOSH 2017b, Issues Resolution Matrix for Fernald Site Profile and SEC Petition, Rev. 05, is more conservative.

SC&A Clarifying Question 7: It is not clear what the final thoron dose assignment is intended to be, as NIOSH 2017a and NIOSH 2017b contain different estimates. In addition, SC&A asks for clarification on the calculation steps presented in NIOSH 2017b, as it appears the conversion from working levels to working level-months in NIOSH 2017b may be in error.

The calculated thoron dose in NIOSH 2017b, Issues Resolution Matrix for Fernald Site Profile and SEC Petition, Rev. 05, is meant to replace the estimates provided in NIOSH 2017a, ORAUT-TKBS-0017-5, Feed Materials Production Center – Occupational Internal Dose Technical Basis Document. The recommendation is to assign thoron doses to radiological workers for the entire period of potential exposure, 1954-2006. This is based on a calculation from October 2017, which uses the highest thoron concentration value from Building 65.

This equation is used to calculate the equilibrium concentration of Rn-220 and progeny.

$$300\ MT \times \frac{1\times 10^{6} g}{MT} \times \frac{9.89\times 10^{4} pCi}{g} \times 1\times 10^{-4}\ release\ fraction \times \frac{1}{1\times 10^{7}\ L} = \frac{300\ pCi}{L}$$

This is used to adjust the equilibrium, apply the occupancy factor and convert from pCi/L to WL.

$$\frac{300\ pCi}{L} \times 0.04\ F_{eq} \times \frac{0.25\ M}{y} \times \frac{L * WL}{7.5\ pCi} = 0.4\frac{WLM}{y}$$

The highest FMPC thoron exposures are likely to be associated with storage facilities because the mass of material in storage exceeds the amount in process daily. Large scale storage operations are typically occupied only a fraction of the work day. Ventilation in storage facilities is likely to be at a lower air change rate when compared to ventilation in a processing facility where vigorous mechanical or chemical processes are conducted. ORAUT-TBKS-017-5, Rev 3, Table B-5, "Summary of thoron exposure estimates", shows, in the last two rows, various storage sites throughout the site's history contained as much as 300 MT (300*106 g) of thorium. Using a value of 0.989*105 pCi/g, there could be 3*1013 pCi of Th-232 in storage.

The thorium in storage was chemically purified at some time prior to storage. That created a disequilibrium between Th-232 activity and Th-228 activity, which would be a variable as a function of time, initially decreasing and then increasing several years later. The time since chemical separation is not known, but assuming only one chemical separation occurred, the disequilibrium cannot be less than 65%, or more than 100%. Since 100% is a bounding assumption, that value is selected. It follows that the bounding activity of Th-228 in storage, and its short-lived the decay product, thoron, will be 3*1013 pCi.

A release fraction for the thoron in storage must be assumed. Release of the inert noble gas thoron under storage conditions occurs by a diffusion process. The short half-life of thoron (56 s) limits the amount of diffusion that can occur before the element loses its noble gas property and diffusion stops. This means that release fractions for material in storage tend to be small. Assuming a relatively large release fraction value of 1*10-4, the airborne thoron activity in a large storage facility is 3*109 pCi. The estimated volume of the airspace in an FMPC storage building is 1*107 L, so the thoron air concentration is 300 pCi/L.

The Potential Alpha Energy Concentration (PAEC) described in Table B-3 shows that there is 1.33 x 105 MeV/L per 7.5 pCi/L of thoron. PAEC can be expressed in Working Level, where 7.5 pCi of thoron in equilibrium with the short-lived decay products equals one Working Level. A 300 pCi/L concentration of thoron in equilibrium with its short-lived decay products is 40 WL.

In a 2006 paper, Harley and Chittaporn reported that the indoor thoron equilibrium factor, Feq, is likely to be 0.02 and cannot exceed 0.04. Feq describes the activity relationship between thoron and its short-lived decay products which contribute to respiratory tract dose. Feq can be used as a factor to modify Working Level. Using a value of Feq of 0.04, the Working Level is 1.6. Assuming an occupancy factor in the storage facility of 25% (three work months per work year) the thoron exposure potential is 0.4 WLM per year.

Additionally, the following information provides a better explanation of how default values for thoron exposure in Building 65 is estimated:

A thoron concentration of 267 pCi/L was measured in Building 65 during the first calendar quarter of 1996, as reported in Renk (SRDB Ref ID # 133254, p.65), using a track-etch device. This was by far the highest reported result in that large data set. Although it is an outlier in the context of the average measurement for that period at Fernald, it probably is an accurate indicator of the thoron concentration in that building.

The Potential Alpha Energy Concentration (PAEC) described in Table B-3 shows that there is 1.33*105 MeV/L per 7.5 pCi/L of thoron. PAEC can be expressed in Working Level, where 7.5 pCi of thoron in equilibrium with the short-lived decay products equals one Working Level. A 267 pCi/L concentration of thoron in equilibrium with its short-lived decay products is 35.6 WL.

In a 2006 paper, Harley and Chittaporn reported that the indoor thoron equilibrium factor, Feq, is likely to be 0.02 and cannot exceed 0.04. Feq describes the activity relationship between thoron and its short-lived decay products which contribute to respiratory tract dose. Feq can be used as a factor to modify Working Level. Using a value of Feq of 0.04, the Working Level is 1.42. Assuming an occupancy factor in the storage facility of 25% (three work months per work year), the thoron exposure potential is 0.36 WLM per year.

Considering that this measured value represented only one calendar quarter out of many, it is unlikely that this is a bounding analysis of the thoron exposure potential in Building 65. A bounding analysis might be expected by increasing the thoron exposure by 50%. This results in a rounded value of 0.5 WLM per year.

The value used to describe the disequilibrium between Th-232 and Th-228 could be any number less than 100%. Triple-separated thorium, with its equilibrium value of 23%, was selected for use when interpreting in vivo lung counting data, because, in that context, a lower value is more favorable to the claimant than a higher value. In the context of thoron exposure based on air concentration of radioactive material, a higher equilibrium value is more favorable. For this calculation, a value of 100% is chosen as a bounding and claimant-favorable assumption.

The value, Feq, used to describe the equilibrium between thoron (Rn-220) and its short-lived decay products, is used to modify the Working Level calculated with the assumption of 100% equilibrium. Values of Feq could range from less than 1% to 100%. Higher thoron exposures result from higher values of Feq. Empirically, Feq has been observed to be very low, only a few percent. In a 2006 paper, Harley and Chittaporn reported on the indoor thoron equilibrium factor and included data from Fernald in the analysis. They concluded that 0.04 was a bounding value.

A release fraction for the thoron from solid thorium metal or sol-gel must be assumed. Release of the inert noble gas, thoron, under storage conditions occurs by a diffusion process. The short half-life of thoron (56 s) limits the amount of diffusion that can occur before the element loses its noble gas property and diffusion stops. This means that release fractions for material in storage tend to be small. We believe that a bounding value for this factor is 1*10-4. When this value is assumed, the thoron exposure calculated in item 1 (above) matches well with the empirically observed thoron exposure shown in item 2 (above).

The thoron exposure for the “Passive storage” period, 1986 through 1987, will be changed to match the thoron exposure assigned during the “Long-term DOE repository storage” period.

In summary, a bounding analysis might be expected by increasing the thoron exposure by 50%. This results in a rounded value of 0.5 WLM per year. This can be assigned to all radiological workers from 1954-2006, and for all locations.