MEMORANDUM

TO: Savannah River Site Work Group
FROM: SC&A, Inc.
DATE: October 11, 2018
SUBJECT: SC&A Review of RPRT-0070 Methods for Th-232 Dose Reconstruction

Introduction and Background

In May 2017, the National Institute for Occupational Safety and Health (NIOSH) released ORAUT-RPRT-0070, *Evaluation of Method for Assessment of Thorium-232 Exposures at the Savannah River Site from 1972 to 1989* (NIOSH 2017a; hereafter "RPRT-0070). During the Advisory Board on Radiation Worker Health meeting on April 14, 2018, SC&A was tasked with evaluating RPRT-0070 as part of the Special Exposure Cohort review process. Prior to the release of this report, methods for thorium-232 (Th-232) dose reconstruction were described in ORAUT-OTIB-0081, Revision 03, *Internal Coworker Dosimetry Data for the Savannah River Site* (NIOSH 2016). In the prior methodology, coworker distributions were developed utilizing available urinalysis data for americium/curium/californium (Am/Cm/Cf) during the period of interest (October 1972 through the end of 1989) and stratified into two separate worker intake groups (construction trade workers and non-construction trade workers). The derived intakes based on the trivalent bioassay data from NIOSH 2016 are summarized in Table 1 for Type M and Type S thorium and the two separate intake groups.

Table 1. Summary of Derived Daily Intake Rates Based on Am/Cm/Cf Bioassay Data (October 1972–December 1989) as Provided in NIOSH 2016

Worker intake group	50th percentile Type M intake (dpm/d)	50th percentile Type S intake (dpm/d)	95th percentile Type M intake (dpm/d)	95th percentile Type S intake (dpm/d)
Non-construction trade workers	4.8	67.6	44.5	626.2
Construction trade workers	5.2	72.7	58.2	874.8

The updated methodology presented in RPRT-0070 provided an alternate method for evaluating thorium exposures during the period 1981–1989 that is based on evaluation of routine air monitoring data and supporting estimates of potential intake using source term data. RPRT-0070 indicates that use of the trivalent actinide bioassay model developed in ORAUT-OTIB-0081 would still be used for the period from October 1972 through May 1980, when evidence suggests that major work with thorium material had ceased.[1] Beginning in mid-1980 or the start of 1981,[2] NIOSH recommends assignment of intakes of thorium based on the censoring level (CL) for routine alpha air sampling data at the Savannah River Site (1×10^{-12} microcuries per cubic centimeter [$\mu Ci/cm^3$]) which would result in a daily intake rate of 14.6 disintegrations per minute per day (dpm/d). This value can be compared to the previous coworker intake values shown in Table 1. NIOSH postulates that the level of exposure based on the air sampling reporting level would bound potential exposures for the following reasons:

1. Ninety-five percent of the sampled alpha air monitoring data for the 773-A Area were below the reporting level used in developing the internal exposure methods presented in RPRT-0070.
2. Alternate methods of assessing potential intake methods, as presented in NUREG-1400 (NRC 1993), would result in estimated intakes of thorium presented in Table 3-4 of RPRT-0070 as more than an order of magnitude lower than those based on the reporting level air sampling approach.
3. Estimated airborne concentrations of thorium based on the previously derived coworker intakes in NIOSH 2016 would result in air concentrations that are 6–7 times higher than the air sampling level of 1×10^{-12} presented in RPRT-0070.

Each of these three important facets of RPRT-0070 are discussed below.

Item 1: Discussion of the Air Sampling Data Evaluated in ORAUT-RPRT-0070

To evaluate available alpha air sampling data for use in dose reconstruction, NIOSH elected to analyze a random sample of daily air sample results in the 773-A Laboratory Areas. The size of the appropriate random sample to be analyzed was determined based on a NIOSH statistical analysis of the gross alpha air sampling at the Plutonium Fuel Form Facility during the 1970s as presented in ORAUT-RPRT-0080, *Potential Neptunium Exposure to Plutonium Fuel Facility Construction Workers in Building 235-F at the Savannah River Site* (NIOSH 2017b). The intent of that report was to evaluate the exposure potential to workers involved in new construction that was occurring inside Building 235-F but outside the actual neptunium billet line. RPRT-0070 does not discuss the applicability of that statistical analysis in in relation to the exposure potential in a different facility (773-A Laboratory Areas) during a different time period (the 1980s). Such a discussion would appear necessary to demonstrate that the statistical analysis and derived random sample sizes in NIOSH 2017b are sufficiently analogous to derive thorium intakes for dose reconstruction as presented in NIOSH 2017a.

Observation 1: The methods used in selecting an appropriate sample size for analysis were based on air sampling data from a separate facility during a separate timeframe. NIOSH should

[1] It should be noted that the issue of the suitability of the internal bioassay monitoring program at the Savannah River Site for the purposes of reconstructing internal doses is the subject of continued Work Group discussions and research conducted by NIOSH, Oak Ridge Associated Universities Team (ORAUT), and SC&A.
[2] It is not clear from RPRT-0070 whether the newly developed thorium dose reconstruction method begins in June 1980 (when large-scale thorium production ceased) or is intended to begin in January 1981, as was indicated in final sentence of Section 1.0 of NIOSH 2017a.

provide a discussion in RPRT-0070 to demonstrate that the statistical analysis of gross alpha air sampling in Building 235-F during the 1970s is sufficiently analogous of the conditions in the 773-A Laboratory Areas during the 1980s to justify its use in defining a random sample size for exposure potential analysis to thorium (1981–1989).

As shown in Item 1 above, NIOSH presents the compelling argument that over 95% of the evaluated air sampling results were below the CL of 1×10^{-12} µCi/cm^3. This is best demonstrated in Figure 3-2, which provides the median percent of the air samples that are above the CL for 4 years: 1975, 1981, 1984, and 1987. This figure is recreated as Figure 1 in this report for convenience.

Figure 1. Figure 3-2 from NIOSH 2017a, Showing Percentage of Air Samples Below the Censoring Level (1×10^{-12} µCi/cm^3)

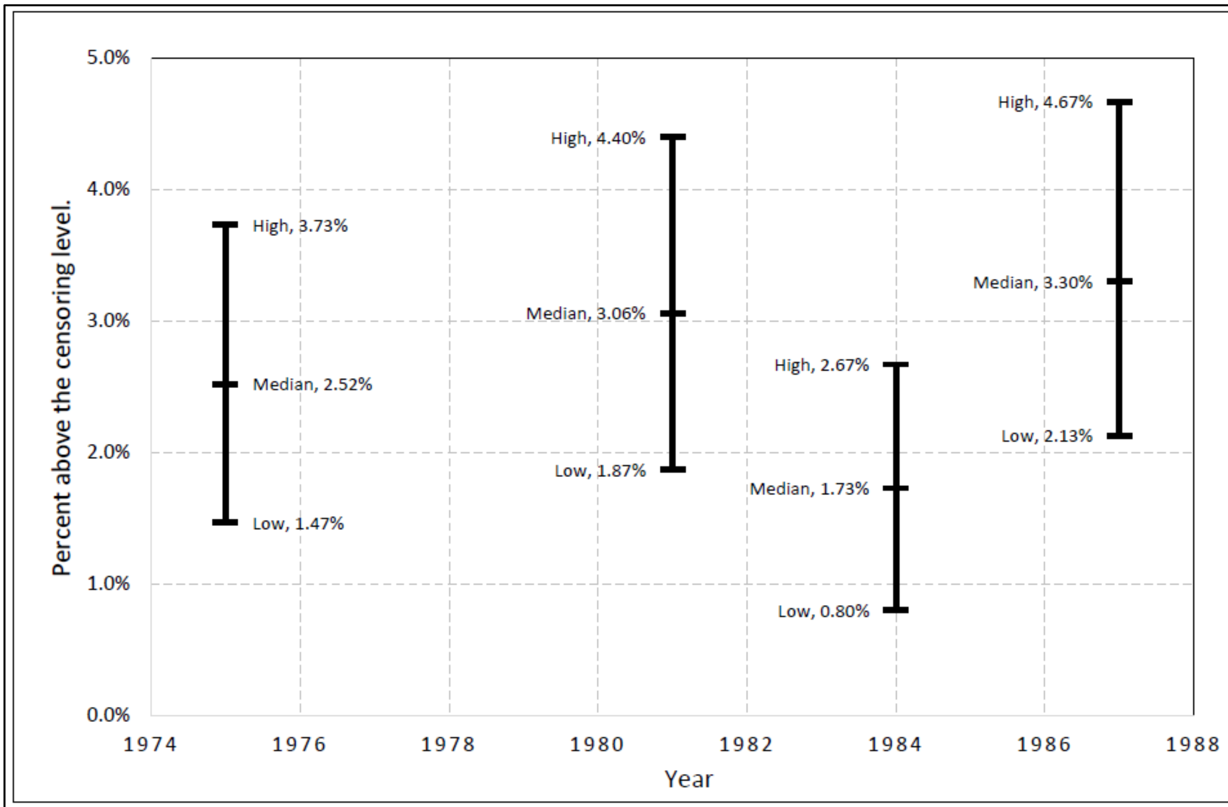

Figure 3-2. Percent of airborne concentration levels above the censoring level. (DuPont 1975a to 1975e, 1981a to 1981f, 1984c to 1984g, 1987b to 1987d).

The period under evaluation in RPRT-0070 spans 1981 through 1989; therefore, the inclusion of 1975 air sampling data does not appear to be relevant to the exposure conditions experienced during the 1980s. In addition, the references provided with Figure 3-2 (in this memo listed as Dupont 1981a–f, Dupont 1984a–e, and Dupont 1987a–c) only provide information on the samples that were above the CL and do not provide the total number of air samples taken during a given measurement period (i.e., the denominator). Therefore, it is unclear how the percentage of samples above the CL for a given monitoring period was determined. One possibility is that the full list of air sampling location codes was assumed to be the entirety of the air monitoring in operation during a given period. However, without actual totals provided to support Figure 3-2, it is not possible to verify that this was the approach taken.

Observation 2: Because the air sampling methodology only applies to the period after May 1980 (or alternately December 1980), it is not clear why NIOSH chose to analyze air sampling data during the year 1975 as shown in Figure 3-2 of RPRT-0070. Inclusion of such data is likely inappropriate.

Observation 3: Given that the cited air sample references only report the values that were above the CL (1×10^{-12} μCi/cm^3), SC&A requests clarification of how the total number of samples (i.e., the denominator) was determined as presented in Figure 3-2 of RPRT-0070.

Although RPRT-0070 presents an analysis of the percentage of air sample data that exceeded the CL, it is equally important to consider the magnitude of the air samples that exceeded the CL and at what locations those measurements occurred to determine the relative impact to exposure potential to a given contaminant and/or work activity. Therefore, SC&A analyzed the available air sample results that reported alpha activities greater than the CL. Table 2 summarizes the sampled data from 1981, 1984, and 1987. As seen in the table, a large percentage of positive air sampling results reported that respiratory protection had been used (~84% for all 3 years combined). SC&A calculated the weighted air concentrations by area in Table 2 by assuming all monitoring periods for a given area in which a positive result was not reported were equal to ½ the CL (0.5×10^{-12} μCi/cm^3). For example, if there were 10 monitoring periods with one monitoring result reported at the CL, the weighted average would be calculated as:

$$[(1 \times CL) + (9 \times ½CL)]/10 = 0.55 \times CL$$

On average, the weighted air concentrations for a given area by year were all less than the CL.

However, some areas had weighted air concentrations that were greater than the CL, with the maximum weighted air concentration approximately 4.65 times the CL. Evaluation of the air monitoring data in 1981 and 1987 showed that approximately 10% of the areas with positive air samples had weighted averages that exceeded the CL. In 1984, the percentage was closer to 20% (10 of 57 locations had weighted averages above the control limit). Table 3 gives additional details about the areas in which weighted air concentrations exceeded the CL.

Table 2. Summary of Positive Alpha Air Monitoring Results Observed for the Years 1981, 1984, and 1987

Time period	1981	1984	1987	All samples
Total air monitoring periods sampled	127	108	60	295
# of positive alpha air samples	469	210	215	894
% of positive results noting respiratory protection used	100.0%	62.8%	73.7%	84.8%
# unique locations reporting positive results	115	56	76	174

Time period	1981	1984	1987	All samples
Weighted average concentration for areas with positive results (× 10^{-12} µCi/cm^3)	0.80	0.94	0.75	0.66
Maximum weighted concentration for areas with positive results (× 10^{-12} µCi/cm^3)	4.65	4.58	2.61	3.81
# of areas with weighted concentrations greater than censoring limit (% of total)	11 (9.6%)	10 (17.9%)	7 (9.2%)	11 (6.3%)

Table 3 shows that the maximum weighted average air concentration was less than a factor of 5 compared to the CL. Notably, the areas where the higher weighted average air concentrations occurred were generally in the high-level cave (HLC) areas, where respiratory protection was at or near 100%. Given that any small-scale handling of thorium during general storage or material transfer activities would likely have been of short duration, SC&A agrees that the use of the CL over the course of an entire year represents a reasonably bounding estimate of thorium exposure under normal conditions.

Table 3. Overview of Locations Displaying Weighted Air Concentrations Greater than the Censoring Level (1×10^{-12} µCi/cm^3)

Year (air sampler location number)	Air sampler location description	# positive samples	Weighted average × CL (1×10^{-12}) µCi/cm^3	% positive results indicating respiratory protection was used
1981 (55, HLC)	773-A (C-118)	30	4.65	100.0%
1984 (55, E Area)	773-A (C-118)	15	4.00	93.3%
1984 (28, E Area)	773-A (B-134)	18	3.56	77.8%
1981 (42, HLC)	773-A (B-155)	30	3.49	100.0%
1981 (29, HLC)	773-A (B-138)	31	3.21	100.0%
1981 (27, HLC)	773-A (B-131)	32	3.20	100.0%
1981 (28, HLC)	773-A (B-134)	31	3.11	100.0%
1981 (41, HLC)	773-A (B-154)	28	3.06	100.0%
1981 (54, HLC)	773-A (C-114)	22	2.86	100.0%
1984 (42, E Area)	773-A (B-155)	15	2.79	86.7%
1984 (29, E Area)	773-A (B-138)	17	2.78	94.1%
1981 (43, HLC)	773-A (B-196)	31	2.77	100.0%
1984 (54, E Area)	773-A (C-114)	14	2.40	85.7%
1984 (43, E Area)	773-A (B-196)	14	2.17	85.7%
1981 (22, HLC)	773-A (B-126)	17	1.93	100.0%
1984 (27, E Area)	773-A (B-131)	17	1.84	82.4%
1984 (41, E Area)	773-A (B-154)	14	1.57	85.7%

Year (air sampler location number)	Air sampler location description	# positive samples	Weighted average × CL (1×10^{-12}) µCi/cm^3	% positive results indicating respiratory protection was used
1987 (9-5)	Lab Area (B-005 NW Center)	16	1.52	93.8%
1987 (9-12)	Lab Area (B-003)	26	1.47	92.3%
1987 (9-1)	Lab Area (B-005 NE)	21	1.27	95.2%
1984 (9-46)	776-4-A (After 1st Stage Filter)	9	1.21	22.2%
1987 (9-2)	Lab Area (B-005 NW)	13	1.19	92.3%
1987 (9-14)	Lab Area *	13	1.19	92.3%
1984 (9-14)	Lab Area *	14	1.12	78.6%
1981 (12, HLC)	773-A (B-114)	2	1.06	100.0%
1981 (9-12)	Lab Area (B-003)	10	1.05	100.0%

* Specific lab area not designated.

Observation 4: Based on SC&A's analysis of the relative magnitude and location of positive air sampling results, SC&A agrees that the use of the CL of 1×10^{-12} µCi/cm^3 over the course of an entire year represents a reasonable upper bound on the exposure potential to thorium under normal conditions associated with storage and material transfer activities.

Item 2: Use of NUREG-1400 Methodology in Dose Reconstruction

In Section 3.1, NIOSH presents an alternate method for estimating intakes of radioactive material that utilizes various correction factors multiplied against known inventory of material; this methodology is outlined in NUREG-1400 (NRC 1993). The fractional intake method takes the known amount of a material in process and uses various correction factors[3] to arrive at an approximate intake over the course of a sufficiently long period of time (nominally 1 year). NIOSH states in Section 4 (pp. 11–12):

> *Based on a source term analysis, NUREG-1400, the average air concentration that a worker could have been exposed to would likely not exceed 1 × 10^{-13} µCi/cm^3….*
>
> *The NUREG-1400 approach likely gives the most realistic exposure estimate for thorium from 1981 to 1989.*

SC&A does not believe the approach or application in this instance is appropriate for dose reconstruction. The methodology presented in NUREG-1400 was meant to help facilities develop an appropriate air monitoring program to protect workers from potential intakes. It was not intended to be used in lieu of an already established air monitoring program or, further, a sufficiently accurate internal monitoring program to evaluate internal dose potential.

In cases where such internal monitoring programs do not exist, the application of NUREG-1400 may be considered acceptable with appropriate conservatism considered. Most recently, NIOSH

[3] The correction factors themselves are presented in Section 3.1 of NIOSH 2017a and so are not discussed here.

has used NUREG-1400, and SC&A has recommended its use be accepted (SC&A 2018), in the evaluation of exposure potential to 23 unmonitored radionuclides at the X-10 site (NIOSH 2018). However, in that case, more viable methods of bounding doses were unavailable, and significant adjustments were made to assure a bounding scenario. Specifically, NIOSH 2018 uses the basic fractional intake multiplier (10^{-6}) and multiplies it by 10 to assure conservatism. Essentially, the NIOSH 2018 application multiples the known amount of material in process by a fractional intake multiplier of 10^{-5}.

In the application of the NUREG-1400 methodology presented in Section 3.1 of RPRT-0070, NIOSH develops a fractional intake factor equal to 10^{-8} (three orders of magnitude lower than that used for the X-10 site). Nonetheless, it should be noted that the NUREG-1400 approach is not being proposed for actual dose reconstruction in this instance. Rather, the method is used as a comparative analysis to justify the use of the air monitoring CL. Therefore, any findings, observations, or further discussion is likely not warranted here.

Item 3: Comparison of Thorium Exposures Using Air Sampling Data versus Derived Coworker Intakes

In the concluding section of RPRT-0070 (Section 4.0), NIOSH states the following:

> *The coworker intakes presented in ORAUT (2016) are considered bounding but result in estimated exposures that are not supported by the air data during the same time period. If* ***routine air concentrations*** *were at the levels associated with the coworker intake rates, there should have been a* ***systemic air concentration*** *6 to 7 times the reporting level. There is no indication of a systemic air concentration above the reporting level; therefore, after 1980, the intake rate based on the reporting level of the air data is considered the best estimate of routine thorium exposure and represents a sufficiently accurate bounding scenario.* [pp. 12–13; emphasis added]

As stated in Observation 4, SC&A agrees that the use of the CL likely represents a sufficiently bounding scenario for exposure to thorium under normal conditions during the period for which no major thorium campaigns were undertaken (1981–1989). However, RPRT-0070 does not address situations in which nonroutine or “off-normal” conditions may have existed. These activities might include direct maintenance, decontamination and decommissioning (D&D), or modification of facility equipment that had previously been used for significant work with thorium. These facilities would also expand beyond the 773-A Laboratory Areas to other areas of potential thorium exposure during nonroutine work conditions.

Finding 1: Per the hierarchy of data criteria, bioassay sampling is considered scientifically preferable to other data and methods, such as the use of air sampling and/or modeling assumptions based on source term inventories. While alternate methods other than the use of bioassay monitoring may be useful in situations where exposure potential is essentially routine or ambient in the facility, such methods may not be applicable to workers involved in off-normal conditions, such as direct maintenance, modification of previously contaminated equipment, or other D&D activities.

Conclusion

While the proposed approach using the CL for alpha air sampling (1×10^{-12} μCi/cm^3) may generally reflect the routine ambient exposure conditions experienced at the Savannah River Site during the period 1981–1989 when little to no thorium was in process, it does not address off-normal conditions such as D&D activities in former thorium work areas. Such activities may create localized exposure potential that may not be captured through routine air sampling or site-wide source term analysis. NIOSH should consider continuing its use of the derived coworker intakes for thorium as presented in ORAUT-OTIB-0081 (NIOSH 2016) for workers potentially involved in off-normal radiological work that may have brought them into contact with thorium.

References

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