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National Institute for Occupational Safety and Health

A Review of ORAUT-TKBS-0003-7 for Savannah River Site – Internal Dosimetry Co-exposure Data

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
Am	americium
CE	co-exposure
CTW	construction trade worker
dpm/d	disintegration per minute per day
DR	dose reconstruction
GSD	geometric standard deviation
IDOT	Internal Dosimetry Tool
IMBA	Integrated Modules for Bioassay Analysis
IR	intake regime
NIOSH	National Institute for Occupational Safety and Health
nonCTW	non-construction trade worker
ORAUT	Oak Ridge Associated Universities Team
SEC	Special Exposure Cohort
SRDB	Site Research Database
SRS	Savannah River Site
SS	super S
TBD	technical base document
Th	thorium

1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. One of those documents is ORAUT-TKBS-0003-7, revision 00, "Savannah River Site – Internal Dosimetry Co-Exposure Data" (ORAUT, 2024a; "TBD-7"), which provides information to allow ORAUT dose reconstructors to assign co-exposure (CE) intakes to Savannah River Site (SRS) workers.

On September 25, 2024, SC&A was tasked by the SRS work group to review the recently revised SRS technical base documents (TBDs). ORAUT-TKBS-0003-7, revision 00 (ORAUT, 2024a), is part of those revised TBDs.

2 Summary of Pertinent SRS Documents

NIOSH issued ORAUT-OTIB-0081 ("OTIB-0081"), "Internal Coworker Dosimetry Data for the Savannah River Site," revisions 00, 01, and 02 in 2013; revision 04 in 2019 (ORAUT, 2019); revision 05 in 2020 as "Internal Dosimetry Co-exposure Data for the Savannah River Site" (ORAUT, 2020b); and informal internally circulated drafts of revisions 06-A and 06-B in 2021 and revision 06-C in 2022. NIOSH incorporated OTIB-0081 into TBD-7 in 2024. The following is a summary of the NIOSH and SC&A documents pertinent to SC&A's review of TBD-7.

- **March,13, 2019:** NIOSH issued ORAUT-OTIB-0081, revision 04 (ORAUT, 2019)
- **September 4, 2019:** SC&A issued revision 0 of its review ORAUT-OTIB-0081, revision 04 (SC&A, 2019)
- **March 13, 2020:** SC&A issued revision 1 of its review of ORAUT-OTIB-0081, revision 04 (SC&A, 2020a)
- **June 3, 2020:** SC&A issued memorandum, "Summary Position on Trivalent Bioassay Variability," to the SRS and SEC Issues work groups (SC&A, 2020b)
- **November 20, 2020:** Transcript of a joint teleconference meeting of the Advisory Board on Radiation and Worker Health (ABRWH) SRS and Special Exposure Cohort (SEC) Issues Work Groups (ABRWH, 2020)
- **April 21, 2022:** SC&A issued memorandum, "SRS Trivalent Bioassay Variability Status and Recommendation," to the SRS and SEC Issues work groups (SC&A, 2022)
- **March 5, 2024:** NIOSH issued ORAUT-TKBS-0003-7, rev. 00 (ORAUT, 2024a)

3 SC&A's Approach to Review of ORAUT-TKBS-0003-7

SC&A reviewed revision 04 of OTIB-0081 in 2020 (SC&A, 2020a). SC&A identified five findings and eight observations. All finding and observations have been addressed and closed except finding 1, concerning variability in trivalent bioassay results (ABWRH, 2020, p. 93). Finding 1 was further reviewed by SC&A (2020b, 2022) and addressed by NIOSH in attachment C of TBD-7, which is discussed in section 4.4 of this report.

Because SC&A (2020a) had reviewed OTIB-0081, revision 04 (ORAUT, 2019), SC&A's approach to reviewing TBD-7 (ORAUT, 2024a) was to identify revisions incorporated into TBD-7 compared to OTIB-0081, revision 04, and to focus on those revisions that could potentially impact internal dose assignments in a claimant's DR. SC&A found many revisions incorporated into TBD-7 compared to OTIB-0081, revision 04; many consisted of editorial changes or were for clarification purposes. However, the major revisions that SC&A identified that could impact DR are as follows:

- Updated and reentered americium bioassay data, revised urinary excretion rates, and revised CE intake rates.
- Revised CE thorium intake rates using updated and reentered americium bioassay data.
- Derived plutonium absorption type super S (SS) CE intake rates.

At the appropriate places in TBD-7, NIOSH noted that because of the SRS SEC for subcontractor construction trade workers (CTWs) the CE intake rates do not apply to subcontractor CTWs between October 1, 1972, and December 31, 1990.

4 SC&A's Review of ORAUT-TKBS-0003-7 Dose Reconstruction Parameters

The following sections analyze revisions incorporated into TBD-7 identified by SC&A that could directly impact DR internal dose assignments.

4.1 Updated and reentered americium bioassay data, revised urinary excretion rates, and revised co-exposure intake rates

NIOSH's updating and reentering the americium bioassay data could potentially impact DR as follows.

4.1.1 Updated and reentered americium bioassay data and revised urinary excretion rates

NIOSH updated and reentered the americium urinalysis data and used the time-weighted one person – one statistic method (ORAUT, 2014) and the multiple imputation method (ORAUT, 2021) to model the americium (Am)-241 bioassay data. The results of NIOSH's analysis of the americium bioassay data are in table 7-6 of TBD-7, which provides the 50th and 84th percentile and geometric standard deviation (GSD) of CE Am-241 urinary excretion rates for non-construction trade workers (nonCTWs) and CTWs for the years 1963–1989.

SC&A reviewed the americium bioassay data and NIOSH's analysis of the data provided in the documents and spreadsheets in "Support Files for ORAUT-TKBS-0003-7, Rev. 00 Zip File" (ORAUT, 2022). SC&A did not identify any findings or observations concerning NIOSH's data analysis methods or the americium urinary excretion rates in table 7-6 of TBD-7.

SC&A notes that NIOSH's decision to recode the americium data[1] may be based, in part, on SC&A's commentary in SC&A (2020b) and subsequent discussions of the joint SRS and SEC Issues work groups (ABRWH, 2020) in which SC&A reexamined the original 2014 americium dataset and the 188 cited examples of significant variability within a single bioassay measurement. During that effort, SC&A noted instances where samples were seemingly invalid due to a variety of issues (e.g., contaminated sample, sample was lost in process, the original sample was likely not a single voiding, transcription errors due to the nature of the handwritten hardcopy records, etc.). SC&A found at least 43 of the 188 cited examples contained such potential errors; thus, SC&A certainly agrees with NIOSH's determination to recode the data set with close scrutiny on each datapoint by a senior health physicist (ABRWH, 2020, p. 123).

4.1.2 Revised americium co-exposure intake rates

NIOSH used the americium urinary excretion rates in table 7-6 of TBD-7 to derive the recommended americium intake rates for Am-241 absorption type M for nonCTWs and CTWs. NIOSH grouped the urinary excretion rates from table 7-6 into periods (intake regimes (IRs)) of similar excretion rates. NIOSH used the Integrated Modules for Bioassay Analysis (IMBA) program to derive the projected 50th and 95th percentile intake rates and the GSD for the appropriate IRs for Am-241 type M. These results are summarized in TBD-7 table 7-19 for nonCTWs and table 7-20 for CTWs. NIOSH used five IRs for nonCTWs for the period 1963–1989 and four IRs for CTWs for the period 1966–1989 because of lack of statistically significant bioassay data for CTWs for the early period of 1963–1965. Additionally, the Am-241 projected 50th, 84th, and 95th percentile intake rates; GSD; and adjusted GSD are listed in table E-1 for nonCTWs and table E-2 for CTWs.[2]

NIOSH performed many IMBA runs using the urinary excretion rates from table 7-6 in order to derive the projected Am-241 intake rates listed in tables 7-19, 7-20, E-1, and E-2. Because of the significant number of IMBA runs required, SC&A checked what it felt was a representative portion of the IMBA runs NIOSH provided in the zip file (ORAUT, 2022) to verify correct bioassay data entries, selection of IRs, and projected intake rates. Additionally, SC&A reviewed NIOSH's IMBA plot of measured bioassay data and fitted bioassay data in each of the IRs of interest. SC&A found the fits between the actual data and bioassay data derived from the CE intakes to be reasonably consistent. SC&A did not identify any findings or observations concerning NIOSH's recommended Am-241 type M intake rates listed in tables 7-19, 7-20, E-1, and E-2 of TBD-7.

4.2 Revised co-exposure thorium intake rates

The process of radiochemical separation for the trivalent radionuclides is shown in figure 7-42 on page 90 of TBD-7. Thorium is carried over in the aliquot containing americium, curium, and californium. As shown in table 7-17 of TBD-7, the chemical extraction efficiency for thorium (97 percent) is approximately the same as for americium (95 percent). Therefore, if it is possible

[1] As noted in section 3 of this report, the americium bioassay data are also used for thorium. In addition to the thorium, the americium data also represent two other trivalent actinides: curium and californium.

[2] The 95th percentile is the 50th percentile value times the GSD raised to the power of 1.645. The adjusted GSD is the derived GSD with any value less than 3.00 adjusted to 3.00, which is claimant favorable.

that there could have been thorium in the bioassay sample, the thorium intake can be analyzed using the americium urinary excretion rate data. NIOSH used the americium urinary excretion rate data from table 7-6 in the IMBA program to derive potential thorium (Th)-232 type M and type S nonCTW and CTW CE intake rates as listed in tables 7-43, 7-44, E-25, and E-26 of TBD-7 for the period November 1, 1972, through May 31, 1980.

No thorium intake is listed in the tables before November 1, 1972, because of the SRS SEC designation specific to thorium established under SEC-00103 (effective March 3, 2012). NIOSH derived the Th-232 intake rates for the period November 1, 1972, through May 31, 1980, using the americium bioassay data. Beginning June 1, 1980, NIOSH lists thorium intakes in table 7-43 and 7-44 based on the guidance in ORAUT-RPRT-0070, revision 00 (ORAUT, 2017),[3] which recommends an intake rate of 4.87 disintegrations per minute per day (dpm/d) from inhalation and 0.1 dpm/d from ingestion.

NIOSH performed many necessary IMBA runs using the urinary excretion rates from table 7-6 in order to derive the projected Th-232 intake rates listed in tables 7-43, 7-44, E-25, and E-26 for the period November 1, 1972, through May 31, 1980. Because of the significant number of IMBA runs required, SC&A determined that a focused review of a subset of the thorium IMBA runs NIOSH provided in the zip file (ORAUT, 2022) was appropriate to verify correct bioassay data entries, selection of IRs, and projected intake rates. Additionally, SC&A reviewed the IMBA plot of measured bioassay data and fitted bioassay data in each of the IRs of interest. SC&A found the fits between the actual data and bioassay data derived from the CE intakes to be reasonably consistent. SC&A did not identify any findings concerning NIOSH's recommended Th-232 type M or type S intake rates listed in tables 7-43, 7-44, E-25, and E-26. However, SC&A did have the following four observations.

Observation 1: Thorium intake start dates in tables 7-43, 7-44, E-25, and E-26 appear to be incorrect

The SRS SEC included the lack of sufficient internal thorium monitoring data with an end date of September 30, 1972, according to TBD-7, page 25. OTIB-0081, revision 04, tables 5-23 and 5-24, lists the start date for thorium as October 1, 1972, which would be correct. However, the thorium intake start date in tables 7-43, 7-44, E-25, and E-26 of TBD-7 is listed as November 1, 1972.

Observation 2: NIOSH used thorium intake rates from ORAUT-RPRT-0070 instead of derived from americium bioassay data

Table 7-6 of TBD-7 provides CE americium excretion rates for the period 1963–1989. However, NIOSH only used these data to derive thorium intake rates for the period 1972–1980 and not for 1980–1989, for which NIOSH used ORAUT-RPRT-0070 intake recommendations (ORAUT, 2017), as indicated on page 91 of TBD-7. However, TBD-7 does not state why this change was made. SC&A assumes that this may have resulted from the statement on page 5 of ORAUT-RPRT-0070 (ORAUT, 2017): "There is no indication that there was any major work with

[3] SC&A reviewed ORAUT-RPRT-0070 (ORAUT, 2017) in October 2018 (SC&A, 2018) and NIOSH responded in December 2018 (NIOSH, 2018). Neither the SC&A review nor the NIOSH response has been discussed by the SRS work group.

thorium between in the May 1980 through 1989 time period." However, this needs to be clarified. As noted previously, ORAUT-RPRT-0070 and its associated review and response documents have not been discussed by the SRS work group.

Observation 3: Thorium ingestion intake rates not addressed for 1972–1980

Generally, ingestion of a radionuclide is associated with inhalation intake per OCAS-TIB-009, revision 0 (NIOSH, 2004), but ingestion intake rates were not listed in tables 7-43 and 7-44 for the 1972–1980 period as they were for the 1980–1989 period.

Observation 4: Thorium intake rates in tables E-25 and E-26 appear to be incomplete

Tables 7-43 and 7-44 both list thorium intake rates for two periods: 1972–1980 (derived from americium bioassay data) and inhalation and ingestion intake rates for 1980–1989 (from ORAUT-RPRT-0070 (ORAUT, 2017). However, tables E-25 and E-26 only list thorium inhalation intake rates for one period, 1972–1980, and not for the other period, 1980–1989, or any ingestion intake rates. It may be that the results of tables E-25 and E-26 were only meant to summarize the information from the intake rates derived from americium bioassay data, but this could result in insufficient total thorium dose assignments if the dose reconstructor only used table E-25 or E-26 and not table 7-43 or 7-44.

4.3 Derived plutonium absorption type SS co-exposure intake rates

NIOSH derived absorption type SS plutonium intake rates for TBD-7. NIOSH used the plutonium urinary excretion rate data in table 7-8 of TBD-7 to derive type SS plutonium intake rates for nonCTWs and CTWs, in addition to the previous intake rates derived for types M and S. (Table 7-8 is the same as table 4-4 of OTIB-0081, revision 04; no new plutonium bioassay data were added and none revised.) NIOSH grouped the urinary excretion rates from table 7-8 into intake periods, IRs, of similar excretion rates. NIOSH used the Internal Dosimetry Tool (IDOT) to derive the projected 50th and 95th percentile intake rates for nonCTWs and CTWs for the period 1955–1990, with corresponding GSD values, as summarized in table 7-24. Additionally, the plutonium projected 50th, 84th, and 95th percentile intake rates, along with the corresponding GSD and adjusted GSD, are listed in table E-5 for nonCTWs and E-8 for CTWs.

NIOSH performed many necessary IDOT runs using the urinary excretion rates from table 7-8 in order to derive the projected type SS plutonium intake rates listed in tables 7-24, E-5, and E-8. Because of the significant number of IDOT runs required, SC&A determined that a focused review of a subset of the IDOT runs NIOSH provided in the zip file (ORAUT, 2022) be checked to verify correct bioassay data entries, selection of IRs, and projected intake rates. Additionally, SC&A reviewed the IDOT plot of bioassay data and projected bioassay values and found them to be reasonable fits between the observed and projected urinalysis results. SC&A did not identify any findings or observations concerning NIOSH's recommended plutonium type SS intake rates listed in tables 7-24, E-5, and E-8 of TBD-7. However, SC&A did have an observation concerning NIOSH's use of the plutonium data in general.

Observation 5: Plutonium data may have needed recoding

No plutonium urinalysis data were added or revised, but SC&A notes that the original plutonium urinalysis datasheets were in a nearly an identical format, and often on the same page as the

americium urinalysis sheets that required recoding. This could indicate that the plutonium data also needed to be recoded.

4.4 Resolution of finding 1 from SC&A's review of ORAUT-OTIB-0081

SC&A's review of OTIB-0081, rev. 04, in 2020 (SC&A, 2020a) identified finding 1, concerning variability in trivalent bioassay results. Finding 1 was further reviewed by SC&A (SC&A, 2020b; SC&A, 2022) and addressed by NIOSH in attachment C of TBD-7 after updating and reevaluating the americium bioassay data. SC&A reviewed NIOSH's further analysis of the variability in trivalent bioassay results in attachment C of TBD-7 and the coefficient of variation derived from the americium bioassay data. SC&A does not find that the variability of the alpha particle counting results from several of the bioassay sample for americium would significantly impact the derived CE americium intake rates for DR purposes and recommends closure of finding 1 of SC&A's review of OTIB-0081, revision 04 (SC&A, 2020a).

5 SC&A's Review of ORAUT-TKBS-0003-7 Methods and Documentation

Revisions incorporated into TBD-7 identified by SC&A that could directly impact DR internal dose assignments were reviewed in section 4 of this report. SC&A also reviewed TBD-7 concerning NIOSH's analytical method and documentation. The results are summarized in the following two sections.

5.1 Methods

SC&A had previously reviewed NIOSH's methods used to derive CE intake rates in their review of OTIB-0081, revision 04 (SC&A, 2020a). TBD-7 contained the same analysis NIOSH used for OTIB-0081, revision 04, plus some expanded analysis for quality assurance in attachment A (pages 126–129, 131–132, 135–142, and 147). SC&A reviewed the additions and revised quality assurance analysis in attachment A and found that the results indicated improved (i.e., more stringent) or identical data transcription and worker classification acceptable error rates for in vitro and in vivo bioassays.

NIOSH recommended on page 98 of TBD-7 that recycled uranium intakes be assigned starting in 1961 along with uranium intakes, but without reference. SC&A searched for verification and found that this was correct per a Westinghouse Savannah River Company (2000) report, "Historical Generation and Flow of Recycled Uranium at the Savannah River Site" (p. 1).

SC&A did not identify any findings or observations concerning NIOSH's analytical methods or results.

5.2 Documentation – table contents and text

SC&A's detailed review of TBD-7 identified the following observations.

Observation 6: Change in table 7-7 tritium dose GSD

Some of the tritium annual dose GSD values for nonCTWs and CTWs in table 7-7, page 49, of TBD-7 are different from the entries in table 4-3 of OTIB-0081, while all the other values remained the same. There was no indication that the tritium was reevaluated for TBD-7.

Observation 7: Some table 7-16 entries need clarification

The nonCTW GSD values (column 4) in table 7-16, page 84, of TBD-7 for 1977–1989 for neptunium contain values that are shifted one row down from the corresponding year compared to the entries in table 4-12 of OTIB-0081, rev. 04 (i.e., the data have been transposed down a cell such that the 1977 GSD in OTIB-0081 became the 1978 GSD in TBD-7, etc.).

Observation 8: Some table 7-34 entries need clarification

The CTW 50th percentile intake rates (columns 3 and 4 for U-232 and U-233, respectively) in table 7-34, page 100, of TBD-7 for 1961–1969 contain values that appear to have been switched in columns 3 and 4 from those listed in table 5-15 of OTIB-0081, revision 04. Additionally, while all the uranium intake rates in the tables remained the same in TBD-7 compared to OTIB-0081, revision 04, the intake rates in column 4 of table 7-34 of TBD-7 are slightly less than the corresponding values in column 3 of OTIB-0081, revision 04 (assuming that columns 3 and 4 of 7-34 had been reversed in order compared to columns 3 and 4 of OTIB-0081). There was no indication that the uranium data were reevaluated for TBD-7.

SC&A noted that the recommended CE intake rates for U-232 and U-233 ended on December 31, 1969, in the tables in TBD-7 compared to an end date of September 30, 1972, in the tables in OTIB-0081, revision 04. This apparently is a result of footnote g. on page 95 of TBD-7 stating that U-233 intakes should end in 1969 per the SRS site description (ORAUT, 2024b, table 2-28, p. 60).

Observation 9: Incorrect text on page 142

TBD-7, attachment A, bottom of page 142, states: “There are no issues with the transcription error rates in this SRS tritium dataset.” However, it should read, “There are no issues with the transcription error rates in this SRS neptunium dataset,” since it is an evaluation of the neptunium data, not tritium.

6 Evaluation of commitments to modify SRS guidance

As an extension of the SC&A review of the 2024 revisions of the SRS TBD, SC&A reviewed the records of issues resolution of previously completed DR case reviews for commitments to change the SRS guidance. Throughout the course of DR issues resolution, it is not uncommon for TBD and other guidance document related issues to be identified. In some instances, as a result of activities by the Subcommittee for Dose Reconstruction Reviews, issues noted in a DR result in commitments by NIOSH to update the guidance when it is revised.

SC&A has reviewed 99 dose reconstructions with U.S. Department of Labor-verified employment at SRS. Of those reviews, the Subcommittee for Dose Reconstruction Reviews has completed the evaluation of 84 SRS dose reconstructions as part of DR review Sets 1 through 31. SC&A limited this evaluation to claims that were part of Sets 6 through 31, as these cases were most likely to have used the previous revisions of the SRS TBD and have completed the issues adjudication. In total, SC&A evaluated issues resolution of 66 DRs. SC&A’s evaluation did not identify any commitments to change the SRS guidance that would impact the guidance in the newly issued ORAUT-TKBS-0003-7.

7 Conclusions

SC&A reviewed TBD-7 (ORAUT, 2024a) and evaluated NIOSH's methodology and recommended intake rates. SC&A focused on major revisions that SC&A identified that could impact DR, and also other revisions that supported NIOSH's recommended intake rates. SC&A identified no findings, but did have nine observations:

- Observation 1: Thorium intake start date in tables 7-43, 7-44, E-25, and E-26 appear to be incorrect
- Observation 2: NIOSH used thorium intake rates from ORAUT-RPRT-0070 instead of derived from americium bioassay data
- Observation 3: Thorium ingestion intake rates not addressed for 1972–1980
- Observation 4: Thorium intake rates in tables E-25 and E-26 appear to be incomplete
- Observation 5: Plutonium data may have needed recoding
- Observation 6: Change in table 7-7 tritium dose GSD
- Observation 7: Some table 7-16 entries need clarification
- Observation 8: Some table 7-34 entries need clarification
- Observation 9: Incorrect text on page 142

8 References

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