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National Institute for Occupational Safety and Health

A Review of ORAUT-TKBS-0003-3 for Savannah River Site – Occupational Medical Dose

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
AF	absorption factor
Al	aluminum
CDC	Centers for Disease Control and Prevention
cGy	centigray
cm	centimeter
DCF	dose conversion factor
DR	dose reconstruction
EAK	entrance air kerma
ENSD	entrance skin dose
EXSD	exit skin dose
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
kerma	kinetic energy released per unit mass
mAs	milliampere-second
mm	millimeter
NCRP	National Council on Radiological Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
ODE	organ dose equivalent
ORAUT	Oak Ridge Associated Universities Team
PA	posterior-anterior
SRDB	Site Research Database
SRS	Savannah River Site
SSD	source-to-skin distance
Sv	sievert
TBD	technical basis document

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-0003-3, revision 06, "Savannah River Site – Occupational Medical Dose" (ORAUT, 2024a; "TBD-3"), which provides information to allow ORAUT dose reconstructors to assign occupational medical dose 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 basis documents (TBDs). ORAUT-TKBS-0003-3, revision 06 (ORAUT, 2024a) is part of those revised TBDs.

2 NIOSH's General Approach to Occupational Medical Dose Reconstruction

2.1 NIOSH's source of data

NIOSH obtained occupational medical examination frequency and x-ray machine technical information from SRS records. NIOSH provides a summary of this information in TBD-3 as follows:

- frequency of chest x-ray screening (summarized in table 3-1 for 1950–present)
- description of x-ray and ancillary equipment (table 3-2 for 1950–present)
- technique factors for x-ray equipment types (table 3-3)
- entrance air kinetic energy released per unit mass (kerma) in air for various projections (table 3-4)

2.2 NIOSH's analysis of data and dose recommendations

NIOSH analyzed the technical information and guidance and provides a summary of dose recommendations in TBD-3 as follows.

- organ dose equivalents (rem) for chest projections (table 3-5 for 1950–present)
- skin dose guidance for chest projections (table 3-6 for years through 1970 and after 1970)
- skin dose (rem) from chest projections (table 3-7 for 1950–present)

As a separate document, NIOSH provided a useful spreadsheet summarizing the derivation and resulting dose values that were used in the tables in TBD-3 (ORAUT, 2024b).

2.3 NIOSH's recommended parameters for assigning dose to the B-lymphocytes

In table 3-8 of TBD-3, NIOSH summarized their recommended Interactive RadioEpidemiological Program (IREP) parameters, as a function of time period and x-ray examination projection, for use in assigning dose to the B-lymphocytes. These parameters include the distribution and values for parameters 1, 2, and 3 for input into IREP.

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

SC&A found that the SRS occupational medical technical basis document has been issued as follows.

- July 15, 2003: revision 00
- August 21, 2003: revision 01
- October 29, 2004: revision 02
- April 5, 2005: revision 03
- November 30, 2009: revision 04
- March 5, 2024: revision 05
- September 12, 2024: revision 06

Revision 00 through revision 03 were issued along with the other sections of ORAUT-TKBS-0003 until 2009 when TBD-3, revision 04, was issued as a standalone document, as were the two 2024 editions.

SC&A could not find indications that the SRS TBD had been reviewed since SC&A's review of ORAUT-TKBS-0003, revision 03, in 2007 (SC&A, 2007). Therefore, SC&A performed a complete review of revision 06 of TBD-3 (ORAUT, 2024a) and presents the results of their review in this report.

3.1 SC&A's review of NIOSH's examination frequency and technical information

SC&A reviewed the Site Research Database (SRDB) documents NIOSH referenced in creating the summary information in tables 3-1 through 3-3. Following is SC&A's evaluation of NIOSH's occupational medical x-ray examination information summarized in those tables.

3.1.1 Frequency of chest x-ray screening, table 3-1

SC&A reviewed NIOSH's referenced documents in note a of table 3-1 and concurs with the information summarized in table 3-1 of TBD-3.

3.1.2 Description of x-ray and ancillary equipment, table 3-2

SC&A reviewed NIOSH's referenced documents in the right-hand column of table 3-2 and concurs with the information summarized in table 3-2 of TBD-3.

3.1.3 Technique factors for x-ray equipment types, table 3-3

SC&A reviewed NIOSH's referenced documents in the right-hand column of table 3-3 and concurs with the information summarized in table 3-3 of TBD-3.

3.2 SC&A's review of NIOSH's kerma and dose recommendations

SC&A reviewed the SRDB documents NIOSH referenced in creating the summary information in tables 3-4 through 3-7. Following is SC&A's evaluation of NIOSH's kerma and dose recommendations in those tables.

3.2.1 Entrance air kerma in air for various projections, table 3-4

SC&A evaluated the kerma values in table 3-4 using the larger of the recommended kerma values in figure A-1 of International Commission on Radiological Protection (ICRP)-34 (ICRP, 1982, PDF p. 85), or from table B.3 of National Council on Radiation Protection and Measurements (NCRP)-102 (NCRP, 1989, PDF p. 56). SC&A found the kerma values in air (at 100 centimeters (cm)) and entrance air kerma (EAK) values (at the appropriate source-to-skin distance (SSD)) listed in the eighth column of table 3-4 of TBD-3 to be correct for the parameters stated in the table.

An example of the EAK for a Type VI posterior-anterior (PA) x-ray examination projection for 5 milliampere-seconds (mAs) at an SSD of 154 cm, using exposure units of centigray (cGy), is as follows.

$$\begin{aligned} &\text{EAK} = \text{air kerma} \times \text{mAs} \times (100\ \text{cm}/\text{SSD})^2 \\ &\text{EAK} = 0.4\ \text{cGy}/100\ \text{mAs} \times 5\ \text{mAs} \times (100\ \text{cm}/154\ \text{cm})^2 \\ &\text{EAK} = 0.008\ \text{cGy} \end{aligned} \quad (1)$$

The result of 0.008 cGy is the exposure value for EAK listed in column 8, row 13 of table 3-4 of TBD-3.

3.2.2 Organ dose equivalents for chest projections, table 3-5

SC&A used the EAK for the associated x-ray examination projection from table 3-4 of TBD-3, in conjunction with the recommended organ dose conversion factors (DCFs) from ICRP-34 (ICRP, 1982) to derive organ dose equivalent (ODE) values and compared them to those recommended in table 3-5 of TBD-3 for the various organs and time periods.

An example for a thyroid ODE for the period October 2014 through present for a PA x-ray examination, in units of rem, is as follows.

$$\begin{aligned} &\text{ODE} = \text{EAK} \times \text{DCF} \\ &\text{ODE} = 0.008\ \text{cGy} \times 0.062\ \text{Sv}/100\ \text{cGy} \times 100\ \text{rem}/\text{Sv} \\ &\text{ODE} = 4.96\text{E-}4\ \text{rem} \end{aligned} \quad (2)$$

This result of 4.96E-4 rem is the value for the thyroid ODE in column 8, row 2 of table 3-5 of TBD-3.

SC&A verified NIOSH's use of a backscatter factor of 1.355 for 2.5 millimeter (mm) aluminum (Al) filtration and 1.405 for 3.5 mm Al filtration (per NCRP-102, table B-8) for deriving the entrance skin dose values in table 3-5 (as recommended in footnote of table 3-5) of TBD-3. SC&A checked the ODE values listed in table 3-5 of TBD-3 for several organs and concurs with NIOSH's ODE recommendations.

3.2.3 Skin dose guidance for chest projections, table 3-6

SC&A compared the recommended skin dose guidance for chest projections from table B-4 for the years through 1970 and table B-8 for years after 1970 of ORAUT-OTIB-0006 (ORAUT, 2019) to the skin dose guidance in table 3-6 of TBD-3. SC&A found that table 3-6 contained the correct skin dose guidance for the various time periods and x-ray examination projections.

3.2.4 Skin dose from chest projections, table 3-7

SC&A evaluated the recommended skin dose from chest projections as a function of time period in table 3-7 of TBD-3. SC&A used the EAK values from table 3-4 of TBD-3 multiplied by the backscatter factor from table B-8 of NCRP-102 (NCRP, 1989) multiplied by the dose derived from using the skin dose guidance in table 3-6 of TBD-3.

An example of the derivation of the exit skin dose (EXSD) for a right front shoulder 1950–1970 PA x-ray examination using an absorption factor (AF) of approximately 50.9 for 2.5 mm Al filtration for an overlaying tissue thickness of 24 cm from table B.7 of NCRP-102 (NCRP, 1989) is as follows. The entrance skin dose (ENSD) of 4.07E-2 rem was obtained from table 3-5 of TBD-3.

$$\begin{aligned} \text{EXSD} &= \text{ENSD} \times (1/(0.9 \times \text{AF})) \\ \text{EXSD} &= 4.07\text{E-}2 \text{ rem} \times (1/(0.9 \times 50.9) \\ \text{EXSD} &= 8.88\text{E-}4 \text{ rem} \end{aligned} \quad (3)$$

A skin dose of 8.88E-4 rem is the value for a right front shoulder 1950–1970 PA x-ray examination in column 3, row 2 of table 3-7 of TBD-3.

SC&A verified several of the ENSD, EXSD, and remote skin dose values in table 3-7 of TBD-3 and found them correct. SC&A concurs with NIOSH's skin dose recommendations in table 3-7.

3.3 SC&A's review of recommended parameters for assigning B-lymphocyte dose, table 3-8

SC&A reviewed NIOSH's recommended parameters for assigning dose to the B-lymphocytes in table 3-8 of TBD-3. SC&A compared the values of the parameters listed in table 3-8 to those provided in the ORAUT statistics team paper, "SRS CLL Organ and Chest x-ray Doses 1970-2023" (ORAUT, 2023, PDF pp. 2–5), and found that the IREP distributions, and values for parameter 1, 2, and 3 in table 3-8 of TBD-3 match those recommended in the ORAUT statistics team paper (ORAUT, 2023).

4 Evaluation of Commitments to Modify the TBD

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 TBD. Throughout the course of DR issues resolution, it is not uncommon for TBD-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 TBD when it is revised.

SC&A has reviewed 99 DRs 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 DRs from DR 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 use the previous revisions of the SRS TBD and have completed the issues adjudication. In total, issues resolutions of 66 DRs were evaluated. SC&A's evaluation did not identify any commitments to change the SRS TBD that would impact the guidance in the newly issued ORAUT-TKBS-0003-3.

5 Conclusions

SC&A reviewed the source documents that NIOSH used to derive the entries in tables 3-1 through 3-8 of TBD-3 and did not identify any errors or issues. SC&A performed various calculations to verify NIOSH-recommended dose values and concurs with NIOSH's recommendations. SC&A reviewed the text of TBD-3 and did not identify any errors or issues.

6 References

International Commission on Radiological Protection. (1982). Protection of the patient in diagnostic radiology (Publication 34). *Ann. ICRP 9*(2-3).

National Council on Radiation Protection and Measurements. (1989). *Medical x-ray, electron beam and gamma-ray protection for energies up to 50 MeV (equipment design, performance and use)* (NCRP Report No. 102, June 30).

Oak Ridge Associated Universities Team. (2005). *Savannah River Site* (ORAUT-TKBS-0003, rev. 03). https://www.cdc.gov/niosh/ocas/pdfs/tbd/srs/srs3.pdf

Oak Ridge Associated Universities Team. (2019). *Dose reconstruction from occupational medical x-ray procedures* (ORAUT-OTIB-0006, rev 06). https://www.cdc.gov/niosh/ocas/pdfs/tibs/or-t6-r6-508.pdf

Oak Ridge Associated Universities Team. (2023). *SRS CLL organ and chest x-ray doses 1970-2023*. SRDB Ref. 199356

Oak Ridge Associated Universities Team. (2024a). *Savannah River Site – Occupational medical dose* (ORAUT-TKBS-0003-3, rev. 06). https://www.cdc.gov/niosh/ocas/pdfs/tbd/srs/srs3-r6-508.pdf

Oak Ridge Associated Universities Team. (2024b). X-ray *dose calculations for SRS (ORAUT-TKBS-0003-3 Rev 06) ORAU Team Spreadsheets.* SRDB Ref. 202635

SC&A. (2007). *Status report on the resolution of the Savannah River Site issues resolution matrix* (addendum to SCA-TR-TASK1-0003). https://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/sca-srsirm-r0.pdf