
Draft

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National Institute for Occupational Safety and Health

A Review of ORAUT-TKBS-0016-5 for Mound Plant – Occupational Internal Dose

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Table of Contents

Abbreviations and Acronyms.....	4
1 Statement of Purpose.....	5
2 Mound Plant Site Profiles and Reviews.....	5
3 SC&A’s Review of TBD-5 Revision 03 Compared to Revision 00.....	6
4 SC&A’s Review Of TBD-5, Revision 03.....	7
4.1 SC&A’s review of tables in TBD-5.....	7
4.2 SC&A’s review of equations used in TBD-5.....	9
4.3 SC&A’s review of dose reconstruction recommendations in TBD-5.....	9
5 Evaluation of Commitments to Modify the TBD.....	10
6 Conclusions.....	11
7 References.....	12

Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
CDC	Centers for Disease Control and Prevention
cpm	count per minute
DL	detection limit
dpm	disintegrations per minute
DR	dose reconstruction
E	counting efficiency
ER	evaluation report
HTO	tritiated water vapor
l	liter
L _d	lower limit of detection
LDL	lower detection limit
μCi/L	microcurie per liter
MDA	minimum detectable activity
mL	milliliter
MP	Mound Plant
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
pCi	picocurie
Po	polonium
Pu	plutonium
SEC	special exposure cohort
SRDB	Site Research Database
TBD	technical basis document
Th	thorium
WLM	working level month
Y	chemical yield

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-0016-5, revision 03, “Mound Site – Occupational Internal Dose” (ORAUT, 2017; “TBD-5”), which provides information to allow ORAUT dose reconstructors to assign occupational internal dose to Mound Plant (MP) workers.

On July 28, 2025, SC&A was tasked by the Subcommittee for Procedures Review to review the most recently revised MP technical basis documents (TBDs). TBD-5 is part of those revised TBDs.

2 Mound Plant Site Profiles and Reviews

SC&A found that the MP occupational internal dose TBD has been issued as follows.

- September 9, 2004: revision 00 (ORAUT, 2004)
- March 13, 2009: revision 00 PC-1 (ORAUT, 2009)
- December 13, 2010: revision 01 (ORAUT, 2010)
- April 18, 2013: revision 02 (ORAUT, 2013)
- March 3, 2017: revision 03 (ORAUT, 2017)

All the MP TBDs were reviewed by SC&A in 2006 and the reviews were combined in one report (SC&A, 2006). In that review, SC&A identified 11 primary issues and 15 secondary issues. Of these issues, six primary issues (presently termed findings) and four secondary issues (presently termed observations) applied to TBD-5, revision 00 (ORAUT, 2004). The MP special exposure cohort (SEC) evaluation report (ER) and SC&A’s review of the ER, followed by the MP work group discussions, took place between 2006 and 2016. Some TBD-5 issues along with the SEC issues were included in the SEC review. The sequence of reviews was as follows:

- July 16, 2006, report: SC&A’s review (SC&A, 2006) of all revision 00 of the MP TBDs
- May 25, 2012, matrix: Summary of site profiles issues (SC&A, 2012) in conjunction with the SEC review
- February 11, 2016, report: SC&A’s review (SC&A, 2016) of the latest revisions of MP TBD-2, -3, -4, and -5 in view of previous site profile issues. For TBD-5 the latest revision was 02. SC&A found that five issues remained open:
 - Matrix Issue 5, Plutonium (Pu)-240, 241
 - Matrix Issue 6, Tritides
 - Matrix Issues 11, 12, and 13, Internal Dosimetry Data Completeness

- April 20, 2016: Per Board Review System, the work group reviewed and closed the remaining matrix issues 5, 6, 11, 12, and 13
- April 27, 2016: NIOSH's matrix (NIOSH, 2016a) summarized their response to previous issues

This present review will focus on the following:

- changes in revision 03 of TBD-5 compared to revision 00
- TBD-5, revision 03, tables, equations, and DR recommendations

3 SC&A's Review of TBD-5 Revision 03 Compared to Revision 00

SC&A reviewed the contents of TBD-5, revision 03, and found that several sections had been added or updated when compared to revision 00:

- Section 5.1: Expanded this section with more details
- Section 5.1.1: Added new section
- Section 5.1.2: Added new section, part of which states, "The information in this TBD facilitates the reconstruction of occupational internal dose to employees of the Mound facility. This TBD does not contain guidance to reconstruct doses at Dayton Laboratory facilities (other than the Mound Laboratory), or for dates earlier than February 1949" (ORAUT, 2017, p. 9).
- Section 5.1.3: Added new section concerning SEC for MP workers, along with effective dates covering the period 1949–1980
- Section 5.3.8: Added new section, "Rare Radioactive Isotope Program"
- Section 5.4.4: Added new table 5-4, "In vivo Counting Systems and MDAs"
- Section 5.7.2: Updated and expanded minimum detectable activity (MDA) information for fecal samples in table 5-8
- Section 5.8.2: Expanded weapons-grade plutonium information
- Section 5.8.2.1: Updated and expanded the use of the MP alternate dissolution model for Pu-238
- Section 5.8.2.2: Added new section, "Special Considerations for Type SS Plutonium-239"
- Section B.6: Condensed information concerning solubility and lung clearance type compared to attachment 5A in revision 00

- Section B.7: Condensed information concerning radionuclide use by location compared to attachment 5B in revision 00

SC&A compared revision 03 of TBD-5 to revision 00. In general, SC&A found both revisions contained the same information but some of the information was organized differently in revision 03, with revision 03 containing additional or updated information where appropriate.

4 SC&A's Review Of TBD-5, Revision 03

SC&A reviewed the tables, equations, and DR recommendations contained in TBD-5, revision 03, to determine the validity and applicability of their content.

4.1 SC&A's review of tables in TBD-5

SC&A reviewed the tables in revision 03 for technical content and also compared them to the corresponding tables in revision 00. SC&A reviewed the Site Research Database (SRDB) documents referenced in the TBD to determine the accuracy of information provided in the tables. In general, SC&A found data in the tables to be correct, with the following exceptions.

4.1.1 Table 5-3 Summary of bioassay methods

Observation 1: Detection limit not same as MDA

Table 5-3 states “. . . blanks counted, detection limits (MDAs) quantified” (ORAUT, 2017, p. 21). This text indicates that the detection limit (DL) is the same as the MDA. This is not always true and the subject of further discussions in subsequent observations contained in this review.

4.1.2 Table 5-6 Reported analytical procedures and MDAs for tritium

Observation 2: Term “MDA” used to replace detection limit values

Table 5-6, page 28, uses the term “MDA” to replace the table 5-4, revision 00, term “detection limit” but includes the same numerical values from table 5-4.

Section 5.5.3, page 27, of TBD-5, revision 03, uses the term “MDA” when referring to 0.01 microcurie per liter of tritiated water vapor and references Technical Manual PD-80030, Issue 1 (Phillips, 1988). However, this reference uses the term “can detect a *minimum concentration* of 0.01 $\mu\text{Ci/L}$ ” [emphasis added] (Phillips, 1988, PDF p. 2).

Another example that indicates that at MP the MDA value was not always equal to the lower detection limit (LDL) value is contained in MLM-MV-93-93-0003, “History of Mound Bioassay Programs, Volume 1” (Meyer, 1992, PDF p. 438). This indicates that the LDL for Pu-238 in 1985 was 0.036 picocurie (pCi), which was less than the MDA for Pu-238 of 0.06 pCi/liter (pCi/l). This indicates that an LDL value is not equal to an MDA value and that MDA values are greater than LDL values.

An MP document (MJW, 2002, PDF p. 386) uses the term “lower limit of detection” (L_d) and defines MDA as follows:

$$\text{MDA} = L_d / (2.2 \times E \times Y)$$

When the counting efficiency (E) is assumed to be 0.50 and the chemical yield (Y) is 0.85 the value of MDA, in units of pCi/l, is equal to 1.1 multiplied by the value of L_d , in units of counts per minute. In that case, the value of MDA is approximately equal to LDL or L_d , but this would not be true for other counting efficiencies and chemical yields. For example, Meyer (1992, PDF p. 432) lists a detector counting efficiency of 0.30; this would result in the value of MDA equal to 1.8 multiplied by the value of L_d .

4.1.3 Table 5-15 Th-230 MDAs (dpm), Table 5-17 Protactinium MDAs, Table 5-18 Uranium MDAs, and Table 5-19 Am-241 and Cm-244 MDAs (dpm/24 hours)

Observation 3: Term used to describe detection limits represents a mixture of L_d , LDL, and MDA

Tables 5-15, 5-7, 5-17, and 5-18 use the term “detection limit” in TBD-5, revision 00. Corresponding tables 5-15, 5-17, 5-18, and 5-19 use the term “MDA” in revision 03. SC&A reviewed the referenced documents for these tables (Barton, 1995; MJW, 2002) and found that terms used to describe detectable limits were a mixture of L_d , LDL, and MDA.

4.1.4 Table 5-20 Rn-222 WLM assumptions for dose reconstruction

Observation 4: Reference not provided

SC&A could not locate any references in TBD-5, revision 03, for the radon-222 working level month (WLM) values recommended in table 5-20, page 44.

4.1.5 Table 5-21 Summary of correction factors and excretion equations

Finding 1: Apparent error in equation and/or text

The first equation for polonium-210 (Po-210), for 1944–1963, contained in table 5-21, page 45, states:

$$\text{Daily Excretion Po-210} = \text{Po cpm}/0.5 \times 0.85/0.1 \times 1400 \text{ mL}/\text{Aliquot mL}$$

The second equation, for 1964–1973, contained in table 5-21, page 45, states:

$$\text{Daily Excretion Po-210} = \text{Po cpm}/0.5 \times 0.85/0.1 \times 1400 \text{ mL}/\text{Aliquot mL}$$

where mL is milliliter and cpm is count per minute

An extraction efficiency of 0.86 is given in the text on page 44 and in footnote d of table 5-21; however, an extraction efficiency of 0.85 is cited in both of these equations in table 5-21 and recommended by Meyer (1992, PDF p. 432).

Additionally, in the second equation, the correction factor for chemical recovery of 0.1 should be 0.63 according to the text on page 44 and table 5-21 footnote d.

4.1.6 Comments concerning other tables

SC&A reviewed the tables in TBD-5, revision 03, in detail. In addition to the four observations and one finding previously stated, some general notes concerning the tables are as follows:

- Table 5-2, page 19, provides additional action level values for americium-241 and curium-244, which were confirmed to be correct as per reference (Barton, 1995).
- Table 5-3, page 20, no longer contains the 1947–1956 data for the Dayton facility that was in TBD-5 revision 00, which is consistent with text in section 5.1.2, page 9 of TBD-5, revision 03.
- Table 5-4, page 22, contains in vivo MDA values, which SC&A found to be correct per table references (Tomlinson et al., 1974, PDF pp. 3, 6; Tomlinson, 1990, PDF pp. 280–284).
- Table 5-7, page 33, no longer contains radionuclides (actinium-227, thorium [Th]-228, and radium-226) that were in the comparable table in TBD-5, revision 00, because these radionuclides are now covered by the MP SEC.
- Table 5-8, page 34, contains MDA information for fecal samples, which SC&A was able to verify using the appropriate reference (Barton, 1995, PDF p. 4). Table 5-21, page 39, of TBD-5, revision 00, only contained the chemical recovery fraction for fecal samples.
- Table 5-11, page 36, contains new information concerning plutonium and americium percent activity versus time compared to table 5-9, page 24, of TBD-5, revision 00. SC&A verified this information was correct per the appropriate reference (BMI, 2003).
- Table 5-13, page 38, incorporates information from DCAS-RPT-005 (NIOSH, 2016b) for the alternate dissolution model for Pu-238.
- Table 5-18, page 42, includes the statement “MDA (MJW 2002b)^b” in the reference column, which should read “MDA (MJW 2002b)^a.” This resulted from an incorrect carryover from table 5-17, page 35, of TBD-5, revision 00.
- Table 5-20, page 44, no longer includes radon-222 WLM information for the SEC period of 1949–1979 compared to table 5-14, page 29, of TBD-5, revision 00.

4.2 SC&A’s review of equations used in TBD-5

SC&A reviewed equations 5-1 through 5-14 and found them to be technically correct and the same as those presented in TBD-5 revision 00. SC&A identified no findings or observations concerning the equations in revision 03 of TBD-5.

4.3 SC&A’s review of dose reconstruction recommendations in TBD-5

SC&A found that in general the DR recommendations are summarized and implicit in the contents of the tables, which SC&A has verified. However, some explicit DR recommendations are provided in the text of TBD-5. A summary of DR recommendations is as follows:

- Page 17, section 5.3.9, second paragraph concerning neptunium-237 and curium-244
- Page 23, section 5.4.4, last paragraph concerning reconciling chest counts with urinalysis

- Page 34, section 5.8, concerning general DR recommendations for primary radionuclides
- Page 35, section 5.8.1, concerning MDA values for Po-210 in table 5-9
- Page 39, section 5.8.3, concerning stable metal tritides
- Page 39, section 5.9.2.1, concerning Th-230
- Page 40, section 5.9.2.2, first paragraph concerning thorium and radium
- Page 41, section 5.9.2.2, last paragraph of section concerning background thorium
- Page 42, section 5.9.4, last paragraph of section concerning uranium
- Page 43, section 5.9.7, fourth paragraph concerning americium and curium MDA values
- Page 57, section B.3, last paragraph concerning tritium dose

SC&A considered the DR guidance to be appropriate and did not identify any findings or observations concerning the DR recommendations in TBD-5, version 03.

5 Evaluation of Commitments to Modify the TBD

SC&A reviewed previous TBD and SEC internal dose issues that NIOSH had committed to resolve by making modifications to TBD-5 (NIOSH, 2016a). These issues and their potential resolutions are summarized as follows:

- Matrix issue 5 (Pu-240, 241): This was a remaining action item that was identified in the SEC matrix. The MP work group closed it, and NIOSH was to confirm a bounding intake for Pu-241 for use in the DR program.
 - Resolution: SC&A finds that the revised and new information in table 5-11 of TBD-5, revision 03, fulfills this commitment.
- Matrix Issue 6 (Tritides): During the MP work group discussion of this SEC issue, NIOSH acknowledged that some consideration was needed by dose reconstructors of “intermediate solubility class” tritium compounds (ABRWH, 2009).
 - Resolution: NIOSH (2016a, p. 1) has determined that this small increment of dose does not increase probability of causation for even the most affected workers (those with respiratory-tract cancers assumed to be exposed over the entire 30-year period). Standard procedure for DR is to use the most claimant-favorable solubility type—NIOSH has not included a repetition of the standard procedure in the TBD. SC&A reviewed this explanation and finds that it fulfills this commitment.
- Matrix Issues 11, 12, and 13:
 - Uncertainties and low recovery for polonium bioassay procedures

- Resolution: According to NIOSH (2016a), the required corrections are summarized in equations 5-4 and 5-5 of TBD-5, revision 03, page 35, and are to be used by the dose reconstructor to reconcile the polonium urinalysis data. SC&A finds that this is essentially the same information provided in section 5.5.1.1 of TBD-5, revision 00. However, this information does provide the dose reconstructor with DR instructions, and SC&A finds that this commitment has been fulfilled.
- Fecal bioassay data issue
 - Resolution: SC&A finds that the revised and new information in table 5-8 of TBD-5, revision 03, page 34, fulfills this commitment.
- Tritium (tritiated water vapor [HTO]) data comparison
 - Resolution: Per TBD-5, revision 03, “For 1957 onward the listed and zero doses may be used, with equation 5-2, [TBD-5, revision 03, page 28] to assign a dose only when dose overestimates are appropriate. If they are not appropriate, it is necessary for the dose reconstructor to review tritium logbooks for the employee’s name for the years in question and to assign dose from tritium bioassay or missed dose based on these records instead” (ORAUT, 2017, p. 38). SC&A agrees with the NIOSH response (NIOSH, 2016a, p. 7). SC&A finds that this commitment has been fulfilled.

6 Conclusions

SC&A reviewed the contents, tables, equations, and DR recommendations in MP TBD-5, revision 03, and identified four observations and one finding summarized as follows.

- Observation 1: Detection limit not same as MDA
- Observation 2: Term “MDA” used to replace detection limit values
- Observation 3: Term used to describe detection limits represents a mixture of L_d , LDL, and MDA
- Observation 4: Reference not provided
- Finding 1: Apparent error in equation and/or text

7 References

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