Draft

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of NIOSH's Program Evaluation Report DCAS-PER-040, "Mallinckrodt TBD Revisions"

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0 (Draft)	8/11/2023	Initial issue
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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
Ac	actinium
AEC	U.S. Atomic Energy Commission
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DR	dose reconstruction
EE	energy employee
ft^2	square feet
h/d	hours per day
HHS	U.S. Department of Health and Human Services
IREP	Interactive RadioEpidemiological Program
MCW	Mallinckrodt Chemical Works
µR/h	microroentgen per hour
mg/m^3	milligram per cubic meter
mrad/h	millirad per hour
mR/h	milliroentgen per hour
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
Pa	protactinium
Pb	lead
pCi	picocurie
PER	program evaluation report
pCi/g	picocurie per gram
pCi/L	picocurie per liter
pCi/yr	picocuries per year
Po	polonium
POC	probability of causation
Ra	radium
SEC	Special Exposure Cohort
SLAPS	St. Louis Airport Site
SRDB	Site Research Database

TBD	technical basis document
Th	thorium
U	uranium
UF_4	uranium tetrafluoride
UO_2	uranium dioxide
UO_3	uranium trioxide
U_3O_8	triuranium octoxide
WLM	working level month

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. In recognition of the fact that all of these supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

A program evaluation report (PER) provides a critical evaluation of the effects that a given issue or programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact on the probability of causation (POC) of previously completed DRs with POCs less than 50 percent.

During a teleconference by the Advisory Board on Radiation and Worker Health (Board) Subcommittee for Procedure Reviews on February 16, 2023, the Board tasked SC&A to review DCAS-PER-040, revision 0, "Mallinckrodt TBD Revisions" (NIOSH, 2013; "PER-040"). In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

- **Subtask 1:** Assess NIOSH's evaluation and characterization of the issue addressed in the PER and its potential impacts on DR. Our assessment intends to ensure that the issue was fully understood and characterized in the PER.
- **Subtask 2:** Assess NIOSH's specific methods for corrective action. When the PER involves a technical issue that is supported by documents (e.g., white papers, technical information bulletins, procedures) that have not yet been subjected to a formal SC&A review, subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, subtask 2 will simply provide a brief summary and conclusion of this review process.
- **Subtask 3:** Evaluate the PER's stated approach for identifying the universe of potentially affected DRs and assess the criteria by which a subset of potentially affected DRs was selected for reevaluation. The second step may have important implications where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH's reevaluation is confined to a subset of DRs that, based on their scientific judgment, have the potential to be significantly affected by the PER. In behalf of subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.
- **Subtask 4:** Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the Board will select the DRs and the total number of DR audits for each PER.)
- **Subtask 5:** Prepare a written report that contains the results of DR audits under subtask 4, along with our review conclusions.

2 Relevant Background Information Pertaining to Facility Operations, Potential Source Terms, and Worker Monitoring Protocols

The following information was obtained from the most current revision of the Mallinckrodt Chemical Company and St. Louis Airport Site technical basis document (TBD), ORAUT-TKBS-0005, revision 03 (ORAUT, 2010; "TKBS-0005"), to present the relevant background for this report. Older versions of the TBD will be referred to as applicable in the appropriate sections for PER-040.

2.1 Facility operations

The Mallinckrodt Chemical Company, also known as Mallinckrodt Chemical Works (MCW), Destrehan Street (downtown site), in St. Louis, Missouri, began research on uranium refining and processing operations in April 1942 under the direction of the Manhattan Engineer District, predecessor agency to the U.S. Atomic Energy Commission (AEC). By July 1942, MCW was producing nearly 1 ton of uranium dioxide (UO_2) per day. Many other work activities were also performed at MCW, such as production of uranium trioxide (UO_3), uranium tetrafluoride (UF_4), uranium derby metal and vacuum recasting of ingot metal, recovery of scrap uranium metal, reprocessing of pitchblende residues to recover uranium, etc. The covered period for this site is 1942–1962. Exposure due to remediation activities is considered for 1995.

In addition, the TBD describes exposures for MCW energy employees (EEs) who worked at the St. Louis Airport (Storage) Site (SLAPS), which received residues from MCW operations during 1946–1958. Thereafter, the site was used for residual storage and disposal until 1967. The covered period for SLAPS is January 3, 1947–1973 and 1984–1998.

2.2 Source terms

MCW used a variety of uranium refining processes, which resulted in changes in source terms and exposure potential. The origin of the ores is also important in considering source terms, because the uranium content in the ores varied greatly. Most of the ore processed at MCW was pitchblende ores from the Belgian Congo. To produce UO_2, feed materials of pitchblende ores contained up to 65 percent to 70 percent triuranium octoxide (U_3O_8) by weight. This pitchblende ore contained high levels of radium (Ra)-226 and other radiological daughter products. Therefore, in general, most of the external doses were from Ra-226 in equilibrium with its daughter products. Thorium (Th)-234 and protactinium (Pa)-234 produced most of the extremity doses, and radon and radioactive dust resulted in internal doses due to inhalation.

Table A-4 of TKBS-0005, revision 03, lists the types and quantities of material produced in association with the uranium refining and related operations.

2.3 Worker monitoring at MCW

2.3.1 Internal monitoring

During the years of UO_2 production at MCW, workers were monitored for uranium and thorium by means of urinalysis. Uranium processing workers were given a pre-employment urinalysis and typically submitted annual urine samples thereafter.

Radon breath analysis was performed for EEs potentially exposed to Ra-226. Typically, the sample frequency was quarterly during the operational period.

For assessing exposure to radon, area radon data were used.

NIOSH concluded that it is not feasible to reconstruct internal dose to MCW workers prior to 1949. It was also determined that it is not feasible to reconstruct internal radiation doses from internal exposure to non-uranium radionuclides (Th-230, Pa-231, and actinium (Ac)-227) through 1958. In addition, NIOSH determined internal dose at the SLAPS cannot be reconstructed with sufficient accuracy during the period January 3, 1947, through November 2, 1971. As a result, the U.S Department of Health and Human Services (HHS) designated classes of employees for inclusion in the Special Exposure Cohort (SEC).

2.3.2 External monitoring

EEs were not individually monitored for external dose prior to June 1945. Starting in June 1945, film badges were issued to all EEs cleared to have access to production areas. With some gaps in monitoring data, weekly film badge records are available from 1946 through 1948; 1950 through 1951; 1952; and 1954 through 1958. Film badge records for the post-operations period may not be available.

An SEC has been issued that states it is not feasible to reconstruct external radiation doses for individuals who worked at MCW prior to 1949.

Although there were sources of neutron exposures at MCW, no neutron monitoring was performed at the site. Neutron doses are derived based on neutron-to-photon ratios.

3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-040

3.1 Chronology of events

ORAUT-TKBS-0005, revision 00: NIOSH issued this site profile for MCW on October 24, 2003 (ORAUT, 2003), which included an exposure matrix to provide data and guidance for DR of MCW and SLAPS workers.

SC&A's Draft Review of ORAUT-TKBS-0005, revision 00: The Board tasked SC&A to conduct a technical review of revision 00 of ORAUT-TKBS-0005. SC&A's (2005) review had five findings that impacted the reconstruction of internal, external, and co-exposure doses.

ORAUT-TKBS-0005, revision 01: NIOSH issued ORAUT-TKBS-0005, revision 01, on March 10, 2005, to incorporate (1) comments in the external dose reconstruction sections, (2) additionally capture information regarding site work and external and radon exposure rates, (3) neutron exposure information, (4) information about SLAPS, and (5) additional guidance to dose reconstructors (ORAUT, 2005).

ORAUT-TKBS-0005, revision 02: NIOSH issued revision 02 of the TBD on June 14, 2007 (ORAUT, 2007), to reflect Board comments and to incorporate SEC information. Additional changes included (1) eliminating errors and extraneous intake tables, (2) clarifying guidance on reconstructing doses from monitoring records and co-exposure data, (3) changing methods for assigning internal intakes, (4) revising operational period dates, and (5) adding a section regarding unmonitored raffinate exposure.

OCAS-PER-015, revision 0: NIOSH issued OCAS-PER-015 (NIOSH, 2007) due to changes introduced in TKBS-0005, revision 02, which resulted in an increase in doses to several pathways. NIOSH reassessed doses for all cases that were evaluated using revision 01 of the TBD with POCs less than 50 percent, which resulted in the rework of 16 cases. SC&A was not tasked with the review of OCAS-PER-015.

ORAUT-TKBS-0005, revision 02 PC-1: This was a page change revision initiated May 25, 2009, to (1) incorporate SEC information to extend the class to December 31, 1958, (2) add information to section 6.5, "Unmonitored Raffinate Exposures (1949 - 1958)," (3) add references, and (4) revise table A-40 to clarify that tabulated intakes represent gross alpha activity and to provide guidance on the isotopic mixture to be applied (ORAUT, 2009).

ORAUT-TKBS-0005, revision 03: On November 22, 2010, NIOSH issued revision 03 of the MCW TBD (ORAUT, 2010). Changes incorporated into revision 03 with potential impacts on previously derived dose estimates included (1) incorporating SEC information for SLAPS, (2) expanding DR instructions specific to SLAPS in a new section 9, (3) clarifying that medical x-ray exposure is not to be assigned at the MCW main site since exams were performed offsite, and (4) clarifying that external exposure to monitored EEs is to be included in DRs for EEs employed prior to 1949.

3.2 SC&A's comments

SC&A reviewed each of the documents leading up to changes incorporated into revision 03 of the MCW TBD. SC&A agrees with NIOSH that these changes and their impacts on MCW worker doses mandate the need for PER-040 (NIOSH, 2013).

There are no findings pertaining to subtask 1.

4 Subtask 2: Assess NIOSH's Specific Methods for Corrective Action

As stated in for subtask 1, the MCW TBD was first issued (revision 00) on October 24, 2003 (ORAUT, 2003), and since that time, the following revisions have been made:

- revision 01, issued March 10, 2005 (ORAUT, 2005)
- revision 02, issued June 14, 2007 (ORAUT, 2007)
- revision 02 PC-1, issued May 25, 2009 (ORAUT, 2009)
- revision 03, issued November 22, 2010 (ORAUT, 2010)

On July 31, 2007, OCAS-PER-015 (NIOSH, 2007) was issued to evaluate the effect of revision 02 on previously completed claims. That PER resulted in NIOSH requesting the return of all previously completed MCW DRs that resulted in a POC less than 50 percent. Therefore, PER-040 considered only the effect of revision 03 on claims that were completed using revision 02 or revision 02 PC-1.

In the publication record of revision 02 PC-1 concerning changes in that revision, ORAUT (2009, p. 3) acknowledged the following:

> Page change initiated to incorporate SEC information on pages 10-13 in Section 1.0 (extension of class to 12/31/1958) as instructed by NIOSH. Updated NIOSH required language on pages 10 and 11 in Section 1.0. Added information on pages 106-108 in Section 6.5. Updated NIOSH reference on pages 106-108, 124, 128 and 216 in Sections 7.1, 7.3, 8.5, 8.6, and Attachment A, respectively. Added reference on page 141 in Reference Section. On pages 158-160, updated NIOSH and ORAUT references in Reference Section. On page 210, updated NIOSH reference in Table A-34. Table A-40 on page 215 was revised to clarify that tabulated intakes represent gross alpha activity and to provide guidance on isotopic mixture to be applied. Incorporates formal internal and NIOSH review comments.

In the publication record of revision 03 of TKBS-0005 concerning changes in that revision, ORAUT (2010, p. 3) acknowledged the following:

> Revision initiated to incorporate SEC-00150 information in Section 1.0 for the St. Louis Airport Storage Site as instructed by NIOSH. Additional changes in document include deletion of Sections 8.4, 8.6, and 8.8 and replacement of the material that is still applicable (considering the SEC determination) along with expanded instruction specific to SLAPS into a new Section, 9.0. In addition, the designation of covered periods noted in Section 1.0 was updated to reflect current program guidance. Incorporates formal internal and NIOSH review comments. Section 7.4 changed to clarify that medical x-ray exposure is not to be assigned at the MCW Destrehan Street Plant due to the fact that the examinations were performed offsite. Section 1, 7.0 and 7.1 changed to clarify that external exposure to monitored employees is to be included in dose reconstructions for individuals employed prior to 1949. This exposure was previously excluded from dose reconstruction reports.

In section 2.0, "Issue Evaluation," of PER-040, NIOSH very briefly summarized the changes in TKBS-0005, revision 03, that could increase dose estimates for either MCW or SLAPS workers:

> Revision 2 of the TBD explained that no internal or external dose could be reconstructed for Mallinckrodt employment from 1942 through 1948 as a result of the SEC-00012 designation. However, in revision 3, it was clarified that external dose could be reconstructed for those with a record of external dose monitoring.
>
> In revision 2 PC-1, guidance was added after table A-40 describing appropriate isotopic ratios to use for internal dose at Mallinckrodt between 1959 and 1962. This change could increase dose for some organs.
>
> Revision 3 increased external penetrating and non-penetrating dose at SLAPS for most years between 1947 and1973 and between 1984 and 1998. Revision 3 also added a radon exposure estimate for SLAPS between 1971 and 1973 and an internal dose estimate from 1984 to 1998.

Additional changes to TKBS-0005 that reduced dose were mainly the elimination of occupational medical x-ray dose. Those are not itemized in this report but are accounted for in any new estimate of dose.

SC&A reviewed and compared TKBS-0005 revision 03 (ORAUT, 2010), to revision 02 PC-1 (ORAUT, 2009) and revision 02 (ORAUT, 2007) to determine changes in revision 03 that could result in an increase in internal or external assigned doses. SC&A evaluated PER-040 (NIOSH, 2013) to determine if PER-040 adequately addressed the changes in revision 03 to ensure that potential increases in dose would be accounted for in reworked claims.

The MCW Energy Employees Occupational Illness Compensation Program Act covered DR periods were 1942–1962 and 1995, and the SLAPS DR periods were January 3, 1947–1973 and 1984–1998.

4.1 SC&A's review of TKBS-0005, rev. 03

SC&A reviewed revision 03 of TKBS-0005 (ORAUT, 2010) and compared the text, figures, and tables in it to revision 02 PC-1 (ORAUT, 2009) and revision 02 (ORAUT, 2007). SC&A then reviewed the changes noted and further analyzed those changes that could potentially increase assigned dose during DR. A summary of the changes identified by SC&A is as follows.

1. Revision 02 explained that no internal or external dose could be reconstructed for MCW employment from 1942 through 1948 as a result of the SEC-00012 designation (HHS, 2005). However, revision 03 clarified that external dose could be reconstructed for those with a record of external dose monitoring.

2. In revision 02 PC-1, guidance was added after table A-40 describing appropriate isotopic ratios to use for deriving internal dose at MCW between 1959 and 1995. This change could increase dose for some organs.

3. Revision 03 increased external penetrating and nonpenetrating doses at SLAPS for most years during 1947–1973 and during 1984–1998.

4. Revision 03 added a radon exposure estimate for SLAPS for 1971 through 1973 and for 1984 through 1998.

5. Revision 03 added an internal dose estimate for SLAPS for 1984–1998.

SC&A also found additional changes made to TKBS-0005 that added clarification, editorial changes, or changes that could reduce the estimated dose. SC&A was not tasked with evaluation those changes; therefore, they are not addressed in this report.

The following section provides more detailed analysis of SC&A's evaluation of these five TKBS-0005 changes and their impact on DR.

4.2 SC&A's evaluation of TKBS-0005 changes

Since SC&A had only previously reviewed revision 00 of TKBS-0005, SC&A's subtask 2 review evaluated the changes made in revision 03 of TKBS-0005 for technical accuracy and applicability to DR and assessed whether these changes were adequately addressed in PER-040. The following subsections summarize SC&A's evaluation of the five TKBS-0005 changes that could increase dose.

4.2.1 External dose during SEC

Revision 02 of TKBS-0005 explained that no internal or external dose could be reconstructed for MCW employment from 1942 through 1948 as a result of the SEC-00012 designation (HHS, 2005). However, revision 03 clarified that external dose could be reconstructed for those with a record of external dose monitoring (ORAUT, 2010, p. 104):

> Prior to 1949, external dose for individuals for whom monitoring data is available should be assigned based on the available monitoring data only without consideration of exposure during periods during which monitoring data is not available.

4.2.2 Isotopic ratio data added to table A-40

In revision 02 PC-1, guidance was added after table A-40 describing appropriate isotopic ratios to use for internal dose at MCW between 1959 and 1995, and the same guidance appears on pages 232–233 of revision 03. This change could increase dose for some organs. SC&A evaluated the text guidance and the table added. NIOSH recommends that:

- If the source term of the exposure is known, it should be used in assigning intakes.
- If the source term cannot be determined, then use the most claimant-favorable of the following:
  - If exposure to uranium raffinates was likely, then the total alpha activity can be distributed as 94.6 percent Th-230 and 5.4 percent Th-227.

– Use the table on page 215 of revision 02 PC-1 or page 233 of revision 03 titled "Total Alpha Source Term Factors – uranium ore" (data reproduced in this review as table 1).

SC&A found that, according to Kuhlman (1955, PDF p. 24), the recommended distribution is based on the isotopic composition of the total alpha activity of the ionium product from MCW. This was determined to be 94.6 percent Th-230 (Th-230 is a daughter in U-238 decay chain) and 5.4 percent Th-227 (Th-227 is a daughter in the U-235 chain through Ac-227 decay).

Table 1. Total alpha source term factors for uranium in equilibrium – uranium ore

Source	Ratio to uranium	Fraction of total gross alpha [a]
Uranium	1	0.4
Th-230	0.49	0.2
Ra-226	0.49	0.2
Pb-210	0.49	0.2
Po-210	0.49	0.2
Pa-231	0.02	0.01
Ac-227	0.02	0.01

[a] Total alpha fraction based on ratio of each nuclide activity to the total alpha emitting fraction (Uranium + Th-230 + Ra-226 + polonium (Po)-210 + Pa-231) and assuming that the lead (Pb)-210 activity is equal to that of Po-210 and the Ac-227 activity is equal to that of Pa-231.

Source: Based on ORAUT (2010), p. 233.

SC&A found that, according to the AEC (1958, PDF p. 32), the air samples around uranium ore (in equilibrium) consisted of approximately 24.6 percent uranium and 12 percent radium, for a ratio of radium to uranium of 0.49. Since Ra-226 is a decay product of Th-230, the thorium/uranium ratio would also be 0.49. Likewise, since Pb-210 and Po-210 are in the decay chain of radium, their ratios to uranium would be 0.49. U-235 is approximately 2 percent of the uranium ore alpha activity and U-235 decays to Pa-231, which then decays to Ac-227; therefore, the Pa-231 and Ac-227 ratio to uranium is 0.02.

SC&A finds that the guidance and table added after table A-40 to be correct and applicable to DR. However, SC&A did have the following observation.

Observation 1:
Table A-40 of TKBS-0005 lists intake values for the period 1959–1962 and 1995 for the MCW DR covered period. However, section 2.0, page 2, of PER-040 indicates that the guidance following A-40 could increase internal dose during 1959–1962. SC&A believes PER-040 should also include 1995.

SC&A also noted that in revision 02, the left-hand column of table A-40 gives the correct units of picocuries (pCi) for inhalation and ingestion. However, in revisions 02 PC-1 and 03, the left-hand column sometimes gives the incorrect units of "phi" for inhalation and ingestion, an apparent editing error.

4.2.3 Added external dose at SLAPS

Revision 03 contains three additions that could increase external penetrating and nonpenetrating dose at SLAPS for certain years between 1947 and 1973. These three additions are as follows.

1. **K-65 gamma dose:** The K-65 storage shed values for "Exposure, % tolerance" in table A-33 in revision 02, page 205, and revision 02 PC-1, page 208, were previously incorrectly listed as a number instead of a percentage. For example, 1,760 was listed as 17.6; this error resulted in the derived gamma dose being 2.2 milliroentgen per hour (mR/h) instead of the correct value of 220 mR/h. This was corrected in table A-33 in revision 03, page 226.

2. **1971–1973 SLAPS external gamma dose:** Revision 03 added external gamma dose for unmonitored SLAPS workers for the period November 3, 1971, through December 31, 1973. NIOSH used the 1971 maximum survey results of 1 millirad per hour (mrad/h) (Lenhard, 1971, PDF P. 4) to derive an annual external gamma dose rate of 2 rem at 2,000 hours per year exposure. NIOSH finds that, based on the thickness of the cover material, no shallow dose needs be assigned.

3. **1984–1998 SLAPS external gamma and beta dose:** Revision 03 added external gamma and beta dose for unmonitored SLAPS workers for the period January 1, 1984–December 31, 1998. NIOSH used the 1979 SLAPS survey conducted by the U.S. Department of Energy (DOE, 1979) to derive an average annual external dose rate of 0.184 rem gamma and 1.120 rem beta.

SC&A verified NIOSH's calculations by using an area (in square feet (ft^2)) weighted average of the maximum dose rate measured in a known elevated activity area (47,500 ft^2) and the maximum dose rate measured in the balance of the fenced area (915,000 ft^2 - 47,500 ft^2 = 867,500 ft^2). The maximum dose rate in elevated activity area was 300 microroentgen per hour (µR/h) gamma and 4.6 mrad/h beta (DOE, 1979, PDF p. 60), and the maximum dose rate in the balance of the area was 80 µR/h gamma and 0.34 mrad/h beta (DOE, 1979, PDF pp. 59 and 55, respectively). Using a weighted average, this results in an exposure of 92 mR/h gamma and 0.56 mrad/h beta, which equates to 0.184 rem/year gamma and 1.120 rem/year beta at 2,000 hours per year exposure.

Observation 2: Periods of assigning beta dose at SLAPS
According to TKBS-0005, revision 03 (ORAUT, 2010, pp. 122–123):

- For January 3, 1947–November 2, 1971, NIOSH recommends assigning beta dose.
- For November 3, 1971–December 31, 1973, NIOSH finds that, based on the thickness of the cover material (1 foot of clean fill added), no shallow dose needs to be assigned.
- For January 1, 1984–December 31, 1998, NIOSH recommends assigning beta dose.

SC&A questions what occurred at SLAPS during the period January 1, 1974–December 31, 1983, that warranted beta dose assignment during the period January 1, 1984–December 31, 1998, when it was not to be assigned for the previous period, November 3, 1971–December 31, 1973.

4.2.4 Radon exposure for SLAPS during 1971–1973 and 1984–1998

Revision 03 added an annual radon exposure estimate of 0.036 working level month (WLM) for SLAPS during the period November 3, 1971–December 31, 1973 (ORAUT, 2010, p. 121) and during the period January 1, 1984 – December 31, 1998 (ORAUT, 2010, p. 122). This radon exposure estimate was derived using a DOE (1979) survey (table 14, PDF p. 67) in which the maximum outdoor radon measurements at or near SLAPS was 0.99 picocurie per liter (pCi/L). Using an outdoor equilibrium factor of 0.3 and 100 pCi/L per working level results in an annual exposure of 0.036 WLM (i.e., 0.99 pCi/L × 0.3 × (1/100 pCi/L) × 12 months per year = 0.036 WLM per year).

4.2.5 Internal dose added for SLAPS during 1947–1971 and 1984–1998

1947–1971: Revision 03, page 120, of TKBS-0005 recommends that internal dose assessments should be completed for any claims that have individual monitoring data for individuals employed at the SLAPS during 1947–1971 but who do not qualify for inclusion in the SEC (HHS, 2010).

1984–1998: Revision 03 of TKBS-0005 recommends that DR for unmonitored workers at SLAPS include inhalation and ingestion intake values of the radionuclides listed in table 9-2, which was derived from the soil concentration values listed in table 9-1. The 95th percentile soil concentration values in table 9-1 were derived using an Argonne National Laboratory (ANL) (1993) soil measurement survey for DOE that provides the 95th percentile values for SLAPS (recommended on PDF page 124) from table 3-4 (PDF pp. 155–156) for U-238 (39 picocuries per gram (pCi/g)), Ra-226 (49 pCi/g), Th-230 (670 pCi/g), and Th-232 (3 pCi/g) (ANL, 1993). The soil concentrations for the other radionuclides listed in table 9-1 (ORAUT, 2010) were derived using the ratios recommended in table 2.15 of the 1993 DOE survey (ANL, 1993, PDF p. 87). NIOSH used a resuspension factor of 0.080 milligram per cubic meter (mg/m^3) as recommended by DOE (ANL, 1993, PDF p. 130).

An example of the derivation of the U-238 inhalation value of 7.5 pCi per year (pCi/yr) in table 9-2 is as follows.

$$\begin{aligned} \text{U-238 inhaled} &= 39\ \text{pCi/g} \times 0.080\ \text{mg/m}^3 \times 0.001\ \text{g/mg} \times 1.2\ \text{m}^3\text{/h} \times 8\ \text{h/d} \times 250\ \text{d/yr} \\ &= 7.5\ \text{pCi/yr} \end{aligned}$$

The ingestion values listed in table 9-2 were derived using OCAS-TIB-009, revision 0 (NIOSH, 2004, p. 4), which recommends that the amount of activity ingested on a daily basis can be approximated by assuming it to be 0.2 times the activity per cubic meter of air. This value is then multiplied by 250 workdays per year and divided by 365 calendar days per year.

4.2.6 SC&A summary

SC&A found that most of the changes in revision 03 were to enable the dose reconstructor to assign dose to unmonitored workers. There are insufficient direct monitoring data to develop an adequate co-exposure model, and the source terms are, in general, not point sources but are distributed. Therefore, the somewhat extensive area and air monitoring surveys performed in the past under DOE contracts are useful to establish upper bounds of potential external dose

exposure rates and internal intake of radionuclides. These upper bound values of exposures and intakes can be used to assist in DR.

4.3 SC&A's comments

SC&A evaluated the technical data used by NIOSH to implement the changes recommended for DR contained in TKBS-0005, revision 03 (ORAUT, 2010), and its application to the DR procedure. This review did not identify any findings but did have two observations. Observation 1 is concerned with the lack of PER-040 guidance for table A-40 applicability to 1995. Observation 2 questions the presence or absence of beta dose during different periods at SLAPS.

5 Subtask 3: Evaluate the PER's Stated Approach for Identifying the Number of DRs Requiring Reevaluation of Dose

5.1 NIOSH's selection criteria

Section 3.0 of DCAS-PER-040 described the following criteria NIOSH used to identify previously completed claims requiring reevaluation using guidance in revision 03 of TKBS-0005 (ORAUT, 2010) and mandated by DCAS-PER-040 (NIOSH, 2013):

- The database of completed DRs was queried for the words "Mallinckrodt," "Destrehan," "Louis Airport," or "SLAP." It should be noted that the PER did not provide the total number of claims that met this query.

- From this list, NIOSH eliminated claims for the following reasons:
  - DR completed prior to June 14, 2007 (the date of TBD revision 02; claims prior to that date were reevaluated under OCAS-PER-015)
  - DR completed after November 22, 2010 (the date of TBD revision 03)
  - Claims that had been pulled from DR by the U.S. Department of Labor
  - Claims with a POC greater than 50 percent
  - Claims that qualified for compensation under an existing SEC (except those that potentially required a DR for medical benefits)
  - DRs that did not use the Mallinckrodt TBD in calculating dose (for example, claims from other sites that were identified because of the text search, but the EE did not work at or visit MCW or SLAPS)

This process resulted in a total of 91 cases to be reevaluated.

The rework of the 91 cases using the current version of the Mallinckrodt TBD resulted in 86 of the 91 cases having POCs less than 45 percent. The POC for three of the remaining five cases fell between 45 percent and 50 percent. For these cases, the Interactive RadioEpidemiological Program (IREP) was run 30 times with 10,000 iterations for each run. The final POCs for these three cases remained below 50 percent. The final two cases resulted in a POC greater than 50 percent.

5.2 SC&A's comments

SC&A does not have access to the database used by NIOSH to identify and quantify those cases that qualified for reevaluation. Therefore, our evaluation is limited to the methodology and criteria employed to identify cases that were potentially impacted by PER-040. SC&A concluded that the search terms are appropriate and all-inclusive, and the screening criteria used to eliminate claims from the total number of identified cases are valid.

There are no findings associated with subtask 3.

6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-040

Previous sections of this report described changes introduced in revisions 02, 02 PC-1, and 03 of the MCW TBD that increased assigned internal and external doses.

For SC&A to satisfy its commitment under subtask 4, it is recommended that cases be selected for our review that reflect these changes and meet the following criteria:

- Employment between 1942 through 1948 where external dose was assigned
- Internal dose assigned at MCW between 1959 and 1962 and in 1995.
- External penetrating and/or nonpenetrating doses at SLAPS for years 1947–1973 and/or 1984–1998.
- Radon exposure assigned for SLAPS between 1971 and 1973, and/or between 1984 and 1998.
- Internal dose assigned for SLAPS within the timeframe 1984–1998.

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