



# DCAS-PER-040, Subtask 4: Review of Four Reworked Cases for the Evaluation of DCAS-PER-040

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# Mallinckrodt Chemical Works operations

- ◆ Mallinckrodt Chemical Company, also known as Mallinckrodt Chemical Works (MCW), Destrehan Street (downtown site), St. Louis, Missouri
- ◆ MCW 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
- ◆ By July 1942, MCW was producing nearly 1 ton of uranium dioxide ( $\text{UO}_2$ ) per day
- ◆ Other activities included:
  - production of uranium trioxide ( $\text{UO}_3$ ), uranium tetrafluoride ( $\text{UF}_4$ )
  - uranium derby metal and vacuum recasting of ingot metal
  - recovery of scrap uranium metal
  - reprocessing of pitchblende residues to recover uranium
- ◆ St. Louis Airport (Storage) Site (SLAPS) received residues from MCW operations during 1946–1958; thereafter, site used for residual storage and disposal until 1967

# MCW site profile revisions

- ◆ MCW technical basis document (TBD) ORAUT-TKBS-0005:
  - Rev. 00, issued October 24, 2003
  - Rev. 01, issued March 10, 2005
  - Rev. 02, issued June 14, 2007
  - Rev. 02 PC-1, issued May 25, 2009
  - Rev. 03, issued November 22, 2009
- ◆ OCAS-PER-015, issued July 31, 2007, to address changes in dose reconstruction (DR) procedures using rev. 02 of ORAUT-TKBS-0005
- ◆ OCAS-PER-015 resulted in NIOSH evaluating all previously completed claims with a probability of causation (POC) of <50 percent

# DCAS-PER-040

- ◆ Issued September 10, 2013
- ◆ Addressed changes in DR procedures introduced in TBD rev. 03
- ◆ Reassessed previous claims completed using rev. 02 or rev. 02 PC-1 of MCW TBD

# Energy Employees Occupational Illness Compensation Program Act coverage

- ◆ MCW covered DR periods were 1942–1962 and 1995
- ◆ SLAPS covered DR periods were January 3, 1947, through December 31, 1973, and 1984–1998

# Radionuclides of dose significance

- ◆ A variety of uranium refining processes resulted in changing source terms and exposure potential.
- ◆ Most ore processed at MCW was pitchblende ores from the Belgian Congo.
- ◆ To produce  $\text{UO}_2$ , feed materials of pitchblende ores contained up to 65 percent to 70 percent triuranium octoxide ( $\text{U}_3\text{O}_8$ ) by weight.
- ◆ The pitchblende ore contained high levels of Ra-226 and other radiological daughter products.
  - Most external doses were from Ra-226 in equilibrium with its daughter products.
  - Th-234 and Pa-234 produced most of the extremity doses.
  - Radon and radioactive dust resulted in internal doses due to inhalation.
- ◆ Table A-4 in rev. 03 of TBD lists the types and quantities of material produced in association with the uranium refining and related operations.

# Reason for issuance of DCAS-PER-040

- ◆ TBD rev. 03 contains several changes in DR covering MCW downtown (Destrehan Street) St. Louis site and SLAPS
- ◆ TBD changes include:
  - Rev. 02 stated no internal or external dose could be reconstructed from 1942 through 1948 as a result of SEC-00012. However, rev. 03 clarified that external dose could be reconstructed for energy employees (EEs) with a record of external dose monitoring
  - Rev. 02 PC-1 added guidance after table A-40 to include isotopic ratios for internal dose between 1959 and 1962, which could increase dose for some organs
  - Rev. 03 increased external dose at SLAPS for most years between 1947 and 1973 and between 1984 and 1998 and also added a radon exposure estimate for SLAPS

# SC&A's review of DCAS-PER-040, tasks 1–3

- ◆ Subcommittee for Procedures Review (SPR) tasked SC&A to review DCAS-PER-040
- ◆ September 21, 2023 – SC&A issued [“A Review of NIOSH’s Program Evaluation Report DCAS-PER-040, ‘Mallinckrodt TBD Revisions,’ rev. 1, to fulfill tasks 1, 2, and 3](#)
- ◆ SC&A had no findings from tasks 1, 2, or 3 and two observations from task 2:
  - Including internal dose from table A-40 for 1995 in DCAS-PER-040
  - Periods of assigning beta dose at SLAPS
- ◆ Both observations discussed and closed at 11/8/2024 SPR meeting

# Subtask 4: Conduct audits of a sample set of reevaluated DRs impacted by DCAS-PER-040

- ◆ SPR tasked SC&A with a review of representative cases
- ◆ NIOSH provided SC&A with four cases
- ◆ September 26, 2024 – SC&A provided a written report of the results of DR audit under subtask 4 to SPR

## Subtask 4: Selection of cases

- ◆ Criterion for selection of cases:
  - Employment during 1942–1948 where external dose was assigned
  - Internal dose assigned at MCW between 1959 and 1962 and/or 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

## Subtask 4: Four cases from NIOSH

- ◆ NIOSH posted data for four cases for SC&A's review
- ◆ One or more of the cases involved the criteria previously listed
- ◆ For each of the reviewed cases, SC&A provided:
  - An overview of the case
  - A brief comparison of applicable doses assigned in the previous and reevaluated DRs
- ◆ As requested by the SPR, SC&A performed a focused review of the reworked cases per changes recommended in DCAS-PER-040

# Case A dose reconstruction

- ◆ EE worked as an operator during early years of operations
- ◆ EE was monitored for external and internal radiation exposure during employment
- ◆ Initial DR performed in 2009
- ◆ DR revised in 2012 per PER-040
- ◆ Both DRs resulted in POC of <50 percent

# Case A: Assessment of external dose

## 2009 DR applied:

- ◆ Appropriate 30–250 kilo-electron volt (keV) photon dose conversion factor (DCF)
- ◆ A neutron-to-photon dose ratio of 0.1 (50th percentile) and an ICRP 60 conversion factor of 1.91
- ◆ A claimant-favorable neutron DCF of 1.000
- ◆ A geometry correction factor (GCF) for the lower torso of 2.1

## 2012 reworked DR applied:

- ◆ Appropriate 30–250 keV photon DCF
- ◆ A neutron-to-photon ratio of 0.23 (95th percentile) and an ICRP 60 conversion factor of 1.91
- ◆ A claimant-favorable neutron DCF of 1.000
- ◆ A GCF for the lower torso of 2.1

# SC&A's evaluation of Case A external dose assignment: Observation 1

- ◆ Reviewed the EE's DOE files for external dose data
- ◆ Was able to duplicate NIOSH's 1947 and 1948 photon dose assignment with the following observation:

Observation 1: Use of geometry correction factor (GCF) and neutron-to-photon ratio during and prior to 1949 is unclear

- NIOSH did not apply GCF of 2.1 to 1947 and 1948 measured photon doses
- NIOSH did not assign 1947 or 1948 missed photon dose or measured or missed neutron dose using neutron-to-photon ratio
- In both 2009 and 2012 DRs, NIOSH assigned 1949 measured and missed photon and neutron-to-photon ratio doses and missed neutron doses
- Neither rev. 03 of ORAUT-TKBS-0005 nor OCAS-TIB-0013 provide clear guidance on these issues

# Case A external dose assignment

- ◆ 2012 DR assigned external dose increased due to:
  - Inclusion of 1947 and 1948 dosimetry data
  - 95th percentile neutron-to-photon ratio

# Case A: Assessment of internal dose

- ◆ 2009 and 2012 reworked DRs:
  - Assigned internal doses using EE's uranium uranalysis data
  - Assigned a relatively small total internal dose
  - Radon exposure was not included because cancer location was not the lung
  - Assigned total internal dose did not change

# SC&A's evaluation of Case A internal dose assignment

- ◆ Changes in internal dose assessment between rev. 02 and 03 of the TBD did not include the period or location of employment for this EE
- ◆ Therefore, SC&A concurs that internal dose should remain unchanged

# Summary of SC&A's evaluation of reworked Case A

- ◆ SC&A did not have any findings and had one observation concerning the 2012 reworked DR for Case A

# Case B dose reconstruction

- ◆ EE worked in production area of plant
- ◆ 1995 was only year PER-040 was applicable for EE
- ◆ EE was not monitored for external or internal radiation exposure during employment
- ◆ Initial DR performed in 2008
- ◆ DR revised in 2012 per PER-040
- ◆ Both DRs resulted in POC <50 percent
- ◆ As directed by SPR, SC&A focused on aspects of DR that were impacted by revisions to TBD, which in this case only included internal dose

# Case B 2008 internal dose reconstruction

- ◆ Assigned internal doses using hypothetical intakes of uranium and radon listed in table A-40 of rev. 02 TBD
- ◆ Assigned a large overestimate of uranium using intake values *per day* instead of per year as provided in table A-40
  - Assigned radon intake of  $2.62\text{E-}2$  working level month (WLM) per year for Plant 7 from table A-40 for a full year when EE was only employed for part of year

# Case B 2012 internal dose reconstruction

- ◆ NIOSH assigned internal doses using hypothetical intakes of uranium and radon per table A-40 of TBD, rev. 03, as follows:
  - Uranium, thorium, and actinium intake values *per year*
  - Radon intake of 1.31 WLM/year for Plant 2 (more claimant favorable) for a full year when EE was only employed for part of year
  - Resulting in a total internal dose of less than half the dose assigned in the 2008 DR
- ◆ 2012 internal dose included thorium and actinium, but used intake values based on per year instead of per day as in 2008

# SC&A's evaluation of Case B internal dose assignment

- ◆ Used the recommended 1995 Plant 1 inhalation and ingestion intakes from A-40 of TBD, rev. 03, in the chronic annual dose (CAD) tool
- ◆ Determined that type S solubility U-234 provided largest dose
- ◆ Derived internal dose that matched that assigned in 2012 DR
- ◆ Radon exposure value, derived from table A-40, matched 2012 DR value

# Case B internal dose assignment

- ◆ Overall, internal dose in 2012 DR decreased compared to 2008 DR because:
  - 2012 DR correctly assigned recommended intakes of picocurie per year instead of picocurie per day
  - The addition of Th-230 and Ac-227 intakes accounted for only half 2012 assigned internal dose
- ◆ Radon exposure assigned in 2012 DR (using radon exposure for Plant 2) increased substantially compared to 2008 DR (that used radon exposure for Plant 7)

# Summary of SC&A's evaluation of reworked Case B

- ◆ SC&A found assumptions used to calculate internal doses to be reasonable
- ◆ SC&A did not have any findings or observations concerning the 2012 reworked DR for Case B

# Case C dose reconstruction

- ◆ EE worked for an extended period at the MCW plant
- ◆ Only PER-040 criterion of 1959–1962 internal intake applied to EE
- ◆ EE was not monitored for external or internal radiation exposure during employment
- ◆ Initial DR performed in 2009
- ◆ DR revised in 2012 per PER-040
- ◆ Both DRs resulted in POC <50 percent
- ◆ As directed by SPR, SC&A focused on aspects of DR that were impacted by revisions to TBD, which in this case only included MCW internal dose

# Case C 2009 internal dose reconstruction

- ◆ Assigned internal doses using 50th percentile intakes of uranium and associated radionuclides using rev. 02 of TBD
- ◆ Radon exposure was not included because cancer location was not the lung

# Case C 2012 internal dose reconstruction

- ◆ Assigned internal doses using 50th percentile intakes of uranium and associated radionuclides using rev. 03 of TBD
- ◆ Radon exposure was not included because cancer location was not the lung

# SC&A's evaluation of Case C internal dose assignment

- ◆ Used the recommended Plant 6E inhalation and ingestion uranium and associated radionuclide intakes from A-40 of TBD, rev. 03, in the CAD tool
- ◆ Determined that type M solubility U-234 provided largest dose
- ◆ Derived internal dose matched that assigned by NIOSH in 2012 DR
- ◆ Concurs with NIOSH that radon exposure should not be included because cancer location was not the lung

# Case C internal dose assignment

- ◆ Internal dose in 2012 DR decreased slightly compared to 2009 DR because:
  - 2009 DR use an overestimating intake location of Plant 4
  - 2012 DR use a reasonable intake location of Plant 6E

# Summary of SC&A's evaluation of reworked Case C

- ◆ SC&A found assumptions used to calculate internal doses to be reasonable
- ◆ SC&A did not have any findings or observations concerning the 2012 reworked DR for Case C

# Case D dose reconstruction

- ◆ EE worked at SLAPS
- ◆ EE was not monitored for external or internal radiation exposure during employment
- ◆ Initial DR performed in 2010
- ◆ DR revised in 2012 per PER-040
- ◆ Both DRs resulted in POC of <50 percent
- ◆ As directed by SPR, SC&A focused on aspects of DR that were impacted by revisions to TBD, which in this case included MCW external and internal doses

# Case D: Assessment of unmonitored external dose

- ◆ 2010 and 2012 reworked DRs applied:
  - Appropriate 30–250 keV photon DCF
  - Unmonitored external dose per rev. 02 of TBD
  - Full year exposure for partial years employment

## Case D: Assessment of other external doses

- ◆ NIOSH did not assign onsite ambient dose in either DR
- ◆ NIOSH assigned occupational medical x-ray dose in both DRs

# SC&A's evaluation of Case D external dose assignment

- ◆ Verified that EE was not monitored for external dose
- ◆ Concur with and was able to duplicate NIOSH's:
  - Unmonitored photon dose in 2012 DR using recommendations in rev. 03 of TBD
  - Occupational medical x-ray dose assignment (SLAPS not excluded)
- ◆ Concurs with NIOSH not assigning onsite ambient dose in either DR

# Case D external dose assignment comparison

- ◆ 2012 DR assigned external dose increased slightly because rev. 03 of TBD recommends a slightly greater unmonitored external dose for the latter employment period than rev. 02

## Case D: Assessment of internal dose

- ◆ Unmonitored inhalation and ingestion intakes/doses per applicable TBD assigned in 2010 and 2012 DRs
- ◆ Unmonitored radon intake/dose per applicable TBD assigned in 2010 and 2012 DRs
- ◆ Internal dose same in both DRs because no changes in recommended intake values

# SC&A's evaluation of Case D internal dose assignment

- ◆ Changes in internal dose assessment from rev. 02 and 03 of ORAUT-TKBS-0005 did not include the period or location of employment for this EE
- ◆ Concurs that internal dose should remain unchanged

# Summary of SC&A's evaluation of reworked Case D

- ◆ SC&A found NIOSH's assumptions to be reasonable and doses were calculated correctly
- ◆ SC&A did not have any findings or observation concerning the 2012 reworked DR for Case D

# Summary of SC&A's evaluation of rework of four cases

- ◆ Concludes that the doses for the four cases were reevaluated in accordance with the requirements of DCAS-PER-040, which addresses changes in MCW site profile
- ◆ Identified no findings and one observation concerning application of GCF
- ◆ Observation would not impact the outcome of the case



# Questions?