Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

A DRAFT REVIEW OF ORAUT-TKBS-0017-5, REVISION 03, FEED MATERIALS PRODUCTION CENTER – OCCUPATIONAL INTERNAL DOSE

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ABBREVIATIONS AND ACRONYMS

ABRWH or Board	Advisory Board on Radiation and Worker Health
Am	americium
Bq	becquerel
BRS	Board Review System
BZ	breathing zone
DAC	derived air concentration
MDA	minimum detectable activity
MgF_2	magnesium fluoride
Nb	niobium
NIOSH	National Institute for Occupational Safety and Health
Np	neptunium
µCi	microcurie
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
OTIB	ORAUT technical information bulletin
ppb	parts per billion
ppm	parts per million
Pu	plutonium
Ra	radium
Rn	radon
ROS	regression on order statistics
Ru	ruthenium
RU	recycled uranium
SEC	Special Exposure Cohort
TBD	technical basis document
Tc	technetium
Th	thorium
TRU	transuranic(s)
TWOPOS	time-weighted one person–one sample
U	uranium

WG	Work Group
Zr	zirconium

1.0 BACKGROUND AND STATEMENT OF PURPOSE

On November 10, 2006, SC&A submitted to the Advisory Board on Radiation and Worker Health (ABRWH or Board) the draft report, SCA-TR-TASK1-0010, *Review of the NIOSH Site Profile for the Fernald Environmental Management Project (Feed Materials Production Center)* (SC&A 2006). The site profile review covered the six volumes of the Fernald technical basis document (TBD)—ORAUT-TKBS-0017-1 though ORAUT-TKBS-0017-6—and identified 33 findings. In October 2013, SC&A submitted report, SCA-SP-IM2013-0045, Revision 0, *Fernald Plant Site Profile Issues Matrix – Draft Preliminary SC&A Assessment* (SC&A 2013), which summarized those findings and other issues that SC&A believed were still open following the addition of two classes of workers to the Special Exposure Cohort (SEC) at the July 2013 Advisory Board meeting.

In April 2014, Revision 1 (SC&A 2014a) to SC&A's site profile issues matrix was submitted, which incorporated the National Institute for Occupational Safety and Health (NIOSH) responses to Revision 0 and SC&A's responses to NIOSH's responses. Subsequent to the release of Revision 1, a Fernald Work Group (WG) teleconference meeting was held on April 15, 2014, at which time 6 of the original 33 site profile findings were recommended to be closed.

Revision 2 to the issues matrix (SC&A 2014b), dated September 1, 2014, incorporated additional SC&A responses based on our focused review of new TBD revisions provided in 2014 and included an attachment with responses for those findings requiring a detailed description. In developing Revision 2, SC&A reviewed the transcripts from 16 successive WG meetings held from August 2007 to July 2013, as well as many white papers and memorandum reports related to the SEC deliberations of the WG during that period.

Subsequent to the release of Revision 2, the Fernald WG met on September 3, 2014, to discuss the status and actions required to close out the remaining site profile findings. During that meeting, an additional 14 findings were recommended to be closed by the WG.

Revision 3 (SC&A 2014c) to the matrix was issued in November 2014. It reflected the discussions and recommendations from the September 3, 2014, WG meeting and provided an updated status of the remaining site profile and SEC issues not recommended for closure at that time.

Revision 4 (SC&A 2016a) to the matrix became effective in May 2016 and reflects the discussions and recommendations from the December 4, 2014, WG meeting. It also provides an updated status of the remaining site profile and SEC issues not currently recommended for closure.

This report identifies unresolved findings from the most recent Fernald issues matrix that are related to the Fernald internal dosimetry TBD, ORAUT-TKBS-0017-5, Revision 03, *Feed Materials Production Center – Occupational Internal Dose* (NIOSH 2017a; also referred to as "TBD-5, Revision 03"), and provides SC&A's recommendations for finding disposition.

1.1 RELEVANT BACKGROUND DOCUMENTS

1.1.1 ORAUT-TKBS-0017-5

The Fernald internal dosimetry TBD, ORAUT-TKBS-0017-5, Revision 00, became effective on May 28, 2004 (NIOSH 2004b). SC&A reviewed the site profile documents in 2006 and submitted the Fernald issues matrix in 2013, after SEC deliberations were completed. The most recent revision of the issues matrix has an effective date of May 2016 (SC&A 2016a).

Revision 01 to ORAUT-TKBS-0017-5 became effective July 22, 2016 (NIOSH 2016b). The revision incorporated responses to comments from various white papers that were consolidated into ORAUT-RPRT-0052, Revision 00, *Feed Materials Production Center Internal Dose Topics* (NIOSH 2011b), and changes in response to internal comments, NIOSH review comments, and SC&A matrix issues. Also included were the coworker data previously contained in ORAUT-OTIB-0078, Revision 03, *Internal Dosimetry Coworker Data for the Feed Materials Production Center* (NIOSH 2015; hereafter referred to as "OTIB-0078").

Revision 02 to ORAUT-TKBS-0017-5 became effective September 30, 2016 (NIOSH 2016d). This revision corrected the recycled uranium (RU) contaminant intakes (becquerel per Bq uranium [Bq/Bq U]) in Table 5-34 and the Silo activity concentrations for radium-228 (Ra-228) and thorium-228 (Th-228). The primary purpose of the revision was to correct tables and typos.

Revision 03 to ORAUT-TKBS-0017-5 became effective March 30, 2017 (NIOSH 2017a). This revision incorporates changes in the interpretation of HIS-20 uranium bioassay data, corrects the specific activity of 1% enrichment uranium for uranium coworker intakes, and revised the uranium coworker methodology in Attachment C. It also addresses ABRWH comments on OTIB-0078.

1.1.2 ORAUT-OTIB-0078

ORAUT-OTIB-0078, *Internal Dosimetry Coworker Data for the Feed Materials Production Center*, was originally issued on August 31, 2009 (NIOSH 2009). Since that date, the document has been revised on three occasions. The latest version, Revision 03, was issued on August 19, 2015 (NIOSH 2015). SC&A reviewed OTIB-0078, Revision 03, and issued SCA-TR-2016-SP004, *Draft Review of ORAUT-OTIB-0078, Revision 03, Internal Dosimetry Coworker Data for the Feed Materials Production Center* (SC&A 2016b), which identified two findings and six observations. Subsequent to the SC&A review, the guidance contained in OTIB-0078 was incorporated into Revision 01 to ORAUT-TKBS-0017-5, and OTIB-0078 was cancelled.

2.0 SUMMARY OF PREVIOUSLY IDENTIFIED ISSUES

Revision 4 to the Fernald issues matrix (SC&A 2016a) identifies 16 findings related to the revision of ORAUT-TKBS-0017-5. Of these, eight were closed in previous WG discussions (TBD 1-6 and SEC 4 and 6b), leaving eight still active as of June 2017 (TBD 7, 8, and 10 and SEC 3 are in progress, and TBD 9, 11, 15, and 29 are in abeyance). SC&A identified two findings and six observations from its review of OTIB-0078, Revision 03 (SC&A 2016b). The OTIB-0078 findings and observations have not been discussed in the WG forum. SC&A also identified seven findings from SC&A's white paper, *Review of Proposed NIOSH Methods for Reconstructing Thorium Doses at Fernald (1979–2006)* (SC&A 2014d).

2.1 EXPOSURE TO URANIUM-POOR RAFFINATE MATERIAL

Section 5.3.5.2 of NIOSH 2017a provides methods for reconstructing doses to raffinate materials for some operations, time periods, and areas at Fernald. These sections describe raffinate exposures to the 1952–1956 K-65 drum transfer operation (Section 5.3.5.2.1), handling/processing of pitchblende ores in 1954–1958 (Section 5.3.5.2.2), and the processing/handling of yellowcake in 1959–1961 (Section 5.3.5.2.3). For the first situation, radon breath data was utilized to back-calculate a radium intake that can then be used to ratio to other raffinate contaminants. The second and third situations utilize uranium urinalysis data and assume that the inhaled material was in equilibrium with Th-230.

However, the remaining open issue concerning raffinates was the potential for internal exposure to "uranium and radium poor" raffinate material for certain areas of the Plant 2/3 operations. This is problematic, as there is very little radium present to allow for radon breath analysis and very little uranium present relative to Th-230 to allow for sufficiently accurate use of uranium urinalysis. This issue was most recently discussed at the December 2014 WG meeting (ABRWH 2014b, pages 128–150). At that meeting, NIOSH proposed that one possible avenue was to look into using daily weighted exposure data in Plant 2/3 and propose a model on how to reconstruct Th-230 exposures to the uranium/radium-poor raffinate material. As a result of that discussion, this issue was designated "in progress" pending the development of a model to reconstruct those potential exposures (ABRWH 2014b, page 150). Currently, the Board Review System (BRS) lists the status of the raffinate-related TBD findings (7 and 8) as "in progress," and SC&A recommends that the status remain unchanged until such time as NIOSH is ready to respond to this particular aspect of raffinate material exposures.

SC&A Recommendation: TBD Findings 7 and 8 should remain "in progress" pending development and discussion of a proposed model to reconstruct internal exposures to uranium/radium-poor raffinate materials.

2.2 CONTAMINANT RADIONUCLIDES IN RECYCLED URANIUM

Section 5.3.3 of NIOSH 2017a provides methods for reconstructing doses to claimants from exposure to impurities in RU. This relates to original TBD Findings 9–11 and SEC Finding 3 in the May 2016 version of the Fernald issues matrix (SC&A 2016b).

RU is uranium that had been previously used as reactor fuel or as target material in plutonium production reactors. After irradiation, the uranium was chemically purified to remove fission products and plutonium and other transuranics (TRU) and was then shipped to the uranium enrichment, fabrication, and production plants for re-use. The RU was separated in the chemical processing plants at Hanford and the Savannah River Site. Because it is not possible to attain 100% product purity in chemical separation processes, this RU was known to contain traces of TRU elements and fission product impurities.

The primary contaminants in RU were plutonium-238 (Pu-238), Pu-239, americium-241 (Am-241), neptunium-237 (Np-237), and a fission product, technetium-99 (Tc-99). The Pu-239, Np-237, and Tc-99 were the radionuclides of greatest concentrations and were tracked and documented for control purposes.

Because this material posed a source of exposure to workers who handled it, and NIOSH really did not have the bioassay or the monitoring data to ascertain intakes of these constituent radionuclides, NIOSH proposed using the uranium bioassay data to derive intakes of these impurities in RU (NIOSH 2008). In this 2008 white paper, NIOSH proposed certain default values on a parts-per-billion uranium mass basis for plutonium, neptunium, and technetium, the three radionuclides of most concern from a dosimetric standpoint. These values were 100 parts per billion for plutonium, 3,500 for neptunium, and 9,000 for Tc-99.

The issue of worker exposures to contaminant radionuclides in RU at Fernald has involved several WG meetings, spanning a period from 2008 to 2012, many white paper exchanges, and the expenditure of considerable Board resources. Given that 6 years have elapsed since the RU issue was discussed in the WG forum, a brief historical summary of the discussions and white paper exchanges regarding the RU issue at Fernald is provided in order to assist the reader.

During the Fernald WG meeting on October 28, 2008, SC&A was tasked with reviewing the NIOSH white paper on RU (ABRWH 2008). The direction provided by the ABRWH stated that SC&A should focus on the appropriateness of the default values selected for RU contaminants (Pu-239/240 [referred to herein as Pu-239], Np-237, and Tc-99) and whether the selected values are bounding for all workers for all time periods. SC&A's white paper on this issue (SC&A 2009) identified 11 findings in the NIOSH white paper, which were the subject of extensive discussion in the January 29, 2010, WG meeting (ABRWH 2010a). SC&A 2009 and the discussion recorded in the January 29, 2010, meeting transcript (ABRWH 2010a) thoroughly describe SC&A's concerns regarding RU. During the January 2010 WG meeting, NIOSH stated that it was not prepared at that time to address the various issues raised but agreed to prepare a response.

Prior to the November 9, 2010, WG meeting, NIOSH submitted the report, *NIOSH Response to SC&A Findings Related to the White Paper on Recycled Uranium at Fernald* (NIOSH 2010b), which provided NIOSH's position on each of the 11 findings in SC&A 2009. The 11 findings and NIOSH's responses to them were the subject of intensive discussion at the November 9, 2010, meeting (ABRWH 2010b). Two principal unresolved issues that emerged from that meeting prompted the Board's request for a second white paper from SC&A. First, SC&A provided a compelling argument for why the 19 subgroup process means derived in DOE 2000 do not provide a firm basis for bounding defaults for TRU and fission products. Second, SC&A's

preliminary review of the dust collector data reported in Appendix B to NIOSH 2008 indicates that the NIOSH default values may not be bounding for some classes of workers in some facilities during the proposed SEC period.

SC&A's second white paper on recycled uranium, *SC&A Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald – A Second White Paper* (SC&A 2011a), was transmitted to the WG prior to the February 8, 2011, WG meeting. That paper identified nine new findings that supported SC&A's position regarding the questionable basis for NIOSH's proposed RU defaults, and that some categories of workers were exposed to TRU and fission product levels in excess of the NIOSH defaults. The issues were discussed in detail at the February 8, 2011, WG meeting (ABRWH 2011a). At that meeting, NIOSH was tasked to respond to SC&A 2011a prior to the next WG meeting, scheduled for April 19, 2011. SC&A 2009 and SC&A 2011a thoroughly described SC&A's concerns regarding RU.

On April 13, 2011, SC&A transmitted Revision 1 to our second white paper on RU at Fernald (SC&A 2011b). That revision contained editorial corrections and a revised Table 2 that limited comparisons of organ doses from intakes of RU constituents to specific absorption classes. Note that Revision 1 did not result in changes to the findings in SC&A 2011). Thus, unless otherwise indicated, all references in this document to SC&A's "second white paper" are to SC&A 2011b.

On April 17, 2011, NIOSH provided a response to SC&A 2011a titled, *NIOSH Response to Draft SC&A Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald – A Second White Paper – February 2011* (NIOSH 2011a). Because SC&A did not have time to prepare a detailed response to NIOSH 2011a prior to the April 19 WG meeting, we prepared preliminary observations for discussion at the meeting (ABRWH 2011b). It is noteworthy that at the April 19 meeting, SC&A was not tasked to respond to NIOSH 2011a or perform any additional work on the RU issue.

At the Advisory Board meeting held in St. Louis, Missouri, May 24–26, 2011, SC&A presented the status of our six main SEC findings regarding Fernald (ABRWH 2011c). Part of that presentation focused on SC&A's preliminary observations on NIOSH 2011a. At the conclusion of the presentation, SC&A was tasked by the Advisory Board to provide a formal response to NIOSH 2011a. On August 4, 2011, SC&A provided a response to NIOSH 2011a titled *SC&A's Evaluation of NIOSH's Response Dated March 31, 2011, to SC&A's Second White Paper on Recycled Uranium (Sec Issue #3) at Fernald* (SC&A 2011c). On August 5, 2011, NIOSH submitted a paper, *Issues Related to the Ability to Bound Internal Dose from Recycled Uranium Trace Level Contaminants at Fernald, Draft 01* (NIOSH 2011c), which outlined its position on RU default values.

On August 11, 2011, the Fernald WG met and again discussed the RU issue, including the concerns raised in SC&A 2011c and the position outlined in NIOSH 2011c. At that meeting, the WG agreed that the new proposed defaults for RU constituent radionuclides presented in NIOSH 2011c probably provide plausible upper bounds for the most highly continuously exposed subgroup of workers, the Plant 5 metal production workers and associated Plant 1 millwrights during the period 1973–1989 (ABRWH 2011d). However, SC&A continued to express concern that another group of workers, those who handled the most highly contaminated feed materials

on the front end of processing operations (Subgroup 10A in DOE 2000), might have experienced exposures at levels higher than the new defaults. NIOSH indicated that it believed that those workers were exposed to the highest concentrations only for brief intermittent periods and would, therefore, be covered by the new defaults. At the conclusion of the August 11, 2011, meeting, the WG tasked NIOSH to provide quantitative evidence that the new proposed RU defaults provide a plausible upper bound for the Subgroup 10A handlers and downblenders. On November 1, 2011, NIOSH provided its analysis (NIOSH 2011d), and on February 6, 2012, SC&A provided its response to NIOSH 2011d. That report, SC&A 2012, provided our final position on the RU issue, excluding potential exposure to Am-241.[1]

The last WG discussion of the main constituent defaults in RU took place on February 9, 2012, wherein the WG reached consensus on default levels of Pu, Np-237, and TC-99 for the periods 1961–1973 and 1973–1986. NIOSH's agreement to those values and the record of WG transference of SEC Issue 3 to the site profile are contained in pages 173–178 of the February 9, 2012, WG meeting transcript (ABRWH 2012), excerpts from which are provided below:

> *CHAIR CLAWSON: So, let me understand, and maybe this is for you, Mark. What we are looking at is a tiered step to be able to, when we do this dose -- I just want to make sure that I am clear that in the earlier years we are going to do, we will do the 100 parts per billion?*
>
> *MR. ROLFES: Yes, for the years that particular uranium was processed at Fernald, we are going to add in 800* [sic] *parts per billion of plutonium on a uranium mass basis, as well as additional intake of 3500 parts per billion and 9,000 parts per billion of neptunium-237 -- excuse me -- 9,000 was neptunium-237; the 3500 is -- I got that backwards. Thirty-five hundred parts per billion of neptunium-237 and 9,000 parts per billion of technetium-99.*
>
> *Then, beginning in, I believe it was 1976, I think was the date -- I will have to take a look back.*
>
> *MEMBER ZIEMER: Seventy-three.*
>
> *MR. STIVER: Seventy-three, I believe.*
>
> *MR. ROLFES: Seventy-three, we would default the 400 parts per billion of plutonium on a uranium mass basis. So, we would be adding in the recycled uranium constituents based upon the reconstructed uranium intakes.*
>
> ….
>
> *CHAIR CLAWSON: I will have to admit, I had to have John help me understand the stair steps. So, I have already been through this in detail.*

[1] At the December 2014 WG meeting, NIOSH agreed to consider the Am-241 issue. TBD-5, Revision 03, provides NIOSH's proposed method for dealing with Am-241; SC&A's response to that topic is provided in this report.

So, if there isn't any other questions, we will accept that and move that to the TBD.

….

MEMBER ZIEMER: So, we consider this issue closed then.

CHAIR CLAWSON: It is closed and moved to the TBD.

Those agreed-upon constituent radionuclide concentration values were subsequently incorporated into Tables 18a and 18b of ORAU-RPRT-0052, Revision 00, dated July 2011 (NIOSH 2011b). Those tables are reproduced below for convenience as Tables 2-1 and 2-2. Note that the radionuclides other than Pu, Np, and Tc-99 in Table 18a were not in contention.

Table 2-1. Recommended RU Default Values Beginning in 1961 and to 1973 (Table 18a, NIOSH 2011b)

RU contaminant	Mass concentration addition	Activity concentration (Bq/g U)
Pu-239	100 ppb U	232.7
Np-237	3,500 ppb U	92.5
Tc-99	9,000 ppb U	5698
Th (232)[a]	10,000 ppb U	0.04
Ru-103/106	50 µCi/lb	4,075
Zr/Nb-95	15 µCi/lb	1,222
Others (Sr-90)	2 µCi/lb	163

a. Th-228 should be assumed to be at 70% equilibrium with Th-232.

Table 2-2. Recommended RU Default Values Beginning in 1973 and to 1986 (Table 18b, NIOSH 2011b)

RU contaminant	Mass concentration addition	Activity concentration (Bq/g U)
Pu-239	400 ppb U	931
Np-237	11 ppm U	291
Tc-pp	20 ppm U	20,000

TBD Findings 9 and 11 in the Fernald issues matrix (SC&A 2016a) were put into abeyance pending inclusion of the Table 18a and 18b values in the revised TBD-5; Finding 10 was in progress pending development of a method for dealing with Am-241 from NIOSH.

Section 5.3.3 of TBD-5, Revision 03 (NIOSH 2017a), addresses the RU issue in general. The new default RU constituent levels are provided in Table 5-10 of NIOSH 2017a, which is reproduced below for the readers' convenience.

Table 2-3. RU Contaminant Mass Concentrations (Table 5-10, NIOSH 2017a)

RU contaminant	1961–1972	1973–present
Pu-alpha[a]	10 ppb U	400 ppb U
Np-237	400 ppb U	11,000 ppb U
Tc-99	6,000 ppb U	20,000 ppb U
Th-232[b]	10,000 ppb U	10,000 ppb U
Ru-103/106[c]	50 µCi/lb	50 µCi/lb
Zr/Nb-95[d]	15 µCi/lb	15 µCi/lb
Sr-90	2 µCi/lb	2 µCi/lb

a. The plutonium alpha mixture is assessed as 100% Pu-239. Am-241 and Pu-241 are assessed based on 6% weapons-grade plutonium mixture.
b. An intake of Th-228 should be added and assumed to be at 70% equilibrium with Th-232.
c. Ru-103/106 is assumed to be 100% Ru-106 due to its longer half-life.
d. Zr-95/Nb-95 pair is assumed to be in equilibrium with equal activities totaling the mass concentrations indicated in the table.

A comparison of Table 18a from NIOSH 2011b and Table 5-10 from NIOSH 2017a reveals that the default values from NIOSH 2011b that were agreed upon by the WG at the February 2012 WG meeting, after years of deliberation, are not those contained in Table 5-10. In fact, the defaults for Pu-239, Np-237, and Tc-99 in Table 5-10 are lower than those in Table 18a of NIOSH 2011b by factors of 10, 8.75, and 1.5, respectively. In arriving at the Table 5-10 values for 1961–1972 contained in the updated TBD, the methodology has ignored the impact of the concentrating mechanism that occurred in the magnesium fluoride (MgF_2) reduction bomb liners, which impacted Plant 5 workers and Plant 1 workers involved in recycling the MgF_2 for reuse. These concerns are described in detail in SC&A 2011b and were the subject of lengthy WG discussions in the April 2011 and August 2011 WG meetings. Those discussions provided the basis for accepting the Table 18a values.

SC&A notes that Tables 5-33 and 5-34 in NIOSH 2017a, Section 5.5.1.4, which are used for assigning intakes of RU constituent radionuclides in dose reconstruction, contain six separate intervals; those intervals, however, do not directly correspond to the intervals in Table 5-9, which are used to account for the ingrowth of Am-241 and Pu-241. Table 5-9 is replicated below as Table 2-4.

Table 2-4. Age of Plutonium Mixture in RU (Table 5-9, NIOSH 2017a)

Period	Age
1961–1965	Fresh
1966–1975	10 Year
1976–1985	20 Year
1986–2006	30 Year

Table 2-5 shows the intervals used in Tables 5-33 and 5-34 in NIOSH 2017a and the changes in intake values for Pu-239 over time. SC&A understands that the break point in 1965 is to account for the change in uranium enrichment from 1 to 2% that is assumed to have taken place that year and that the 1975–1976 break point is to account for the ingrowth of Am-241 and Pu-241. SC&A

is not clear, however, as to why the Pu-239 intakes go down post 1973 when a constant concentration of 400 parts per billion (ppb) U is assumed for that period. NIOSH needs to explain this.

Table 2-5. Intervals from Tables 5-33 and 5-34 and Changes in Intake for Pu-239

Radionuclide	1961–1964 Bq/g U	1965 Bq/g U	1966–1972 Bq/g U	1973–1975 Bq/g U	1976–1985 Bq/g U	1986 on Bq/g U
Pu-239	29.6	29.6	29.3	1170	1160	1150

SC&A Recommendation: TBD Findings 9 and 11 and the aspect of SEC-P 3 dealing with Pu-239, Np-237, and Tc-99 should be changed from "in abeyance" to "in progress," based on the concerns outlined above.

TBD Finding 10 and Finding SEC-P 3 concern the inclusion of Am-241 in the recycled uranium contaminants. Section 5.3.3.4 of NIOSH 2017a addresses this issue and states:

> *The mass balance reports established that most of the RU came from Hanford and was recycled from weapons-grade plutonium. Therefore, a 6% weapons-grade mixture that had been chemically purified in 1961 was selected for bounding calculations. For dose reconstruction, the plutonium alpha dose from the plutonium mixtures in RU is assumed to be from 100% ^{239}Pu. Plutonium mixture ratios for fresh, 10-, 20-, and 30-year aged intervals after purification were used to estimate the ^{241}Pu and ^{241}Am contaminant levels.*

SC&A Recommendation: Based on the RU contaminant information cited above, TBD Finding 10 regarding the inclusion of Am-241 as an RU contaminant can be changed from "in progress" to "closed," and the aspect of Finding SEC-P 3 dealing with Am-241 can be changed from "in progress" to "closed."

2.3 INGESTION INTAKES FROM THORIUM

During SC&A's review of ORAUT-TKBS-0017-5, Revision 00, SC&A noted that NIOSH proposed to use air concentration data for thorium dose reconstruction that would not consider ingestion dose separately. This led to TBD Finding 15 stating that ingestion doses from Th-232 need to be explicitly considered, unless sufficient personal monitoring data are also found for thorium.

The most recent TBD revision, ORAUT-TKBS-0017-5, Revision 03 (NIOSH 2017a), addresses thorium ingestion in Section 5.5.2.1.2 for 1995 through 2006, where thorium doses are typically based on breathing zone (BZ) data:

> *Ingestion intakes are also assigned when only BZ data are used to assign inhalation intakes (i.e. there are no in vitro or in vivo bioassay), as described in OCAS-TIB-009,* Estimation of Ingestion Intakes *(NIOSH 2004*[a]*).*

Section 5.5.2.3.2 addresses airborne thorium concentrations from 1990 to 1994:

Although the thorium exposure in 1990 could be limited to January to May 1990 (due to 5 months of Project 2 duration), a full year of exposure should be assumed as favorable to claimants. Attachment G, Class W Thorium-232 Inhalation Intake Rate Based on 10% of the Derived Air Concentration, provides the assumptions used to derive these intake rates. Ingestion doses are assigned as described in OCAS-TIB-009, Estimation of Ingestion Intakes *(NIOSH 2004*[a]*), where the amount of activity ingested on a daily basis can be approximated assuming it to be 0.2 times the activity per cubic meter of air.*

SC&A Recommendation: The OCAS-TIB-009 methodology for assessing ingestion intakes has been previously reviewed and accepted. SC&A suggests Finding 15 be changed from "in abeyance" to "closed."

2.4 K-65 SILO RADON EXPOSURE

Revision 00 to ORAUT-TKBS-0017 described the procedure for estimating radon dose to those workers who opened the K-65 waste drums and load Silos 1 and 2 based on just two radon data points from 1953 and attempted to bound the internal intakes by using incorrect external dose limits. SC&A requested that NIOSH justify its assignment of radon dose to these workers, which resulted in Finding 29. This issue was last discussed at the September 3, 2014, WG meeting (ABRWH 2014a, page 240). It was determined that NIOSH would incorporate the methods employed in ORAUT-RPRT-0052 into the Fernald internal dose TBD (ORAUT-TKBS-0017-5). SC&A has reviewed Section 5.3.5.2 of ORAUT-TKBS-0017-5, Revision 03, and determined that NIOSH has applied ORAUT-RPRT-0052 methodology, which uses radon breath analysis for determining a radium intake rate.

SC&A Recommendation: The use of radon breath analysis data for determining intake rates of Ra-226 is a reasonable approach. Therefore, SC&A suggests Finding 29 be changed from "in abeyance" to "closed."

2.5 UNMONITORED INTERNAL DOSE TO URANIUM

NIOSH approved Revision 03 to OTIB-0078 (NIOSH 2015), which provided updated calculations and methods for assessing available uranium urinalysis data for the purpose of assigning uranium intakes to unmonitored workers. On May 12, 2016, SC&A delivered its review of OTIB-0078 (SC&A 2016b), which contained two findings and six observations. It is important to note that, subsequent to the release of NIOSH 2015 and SC&A 2016b, the method for calculating unmonitored uranium intakes utilizing coworker urinalysis results was merged into Attachment C of the Fernald internal dose TBD (NIOSH 2017a).

On July 15, 2016, NIOSH provided responses to SC&A 2016 Finding 1 and Observations 2-6 (NIOSH 2016a). At that time, Observation 1 required the exchange of calculation files between NIOSH and SC&A to effectively address the observation. After the exchange of the required information, NIOSH provided its official response to Observation 1 via email on August 3, 2016 (NIOSH 2016c). Finally, NIOSH provided a response to Finding 2, which was loaded to the BRS in May 2017 (NIOSH 2017b). The following paragraphs describe the original issues, NIOSH's response, and SC&A's recommendation to the WG.

Finding 1 noted that in preparing the HIS_20 database for coworker analysis, values that were reported as negative or zero were censored at the lowest observed positive result in the relevant year. NIOSH's response indicated (1) that the original OTIB-0078 had predated the implementation of the statistical policies found in ORAUT-RPRT-0053, Revision 02, *Analysis of Stratified Coworker Datasets* (NIOSH 2014b) and (2) that future revisions would correctly handle the censoring of negative values by censoring them at "zero." However, it is not clear to SC&A that the updated version of the coworker model found in Attachment C of NIOSH 2017a has implemented this change. Specifically, Attachment C, Section C.3, of NIOSH 2017a still contains the original language from OTIB-0078 (NIOSH 2015):

> *For years with uncensored data,* ***values less than or equal to zero were treated as being censored at the lowest positive value*** *in that year for TWOPOS implementation.* [emphasis added]

It is possible that this language is simply an artifact of earlier versions of the coworker model and the changes to negative and zero values were implemented in the most recent analysis. SC&A requests clarification from NIOSH as to whether the appropriate adjustments were made; therefore, SC&A recommends Finding 1 be put "in abeyance" pending additional information. It should be noted that Observation 3 and Finding 1 deal with the same issue (treatment of values below the minimum detectable activity [MDA]); thus, SC&A recommends that Observation 3 also be put "in abeyance."

A response to Finding 2 was provided by NIOSH via the BRS and was uploaded in May 2017 (NIOSH 2017b). SC&A's original finding had noted that there were pairs of bioassay results for the same worker on the same day that were exactly two orders of magnitude different. SC&A recommended that NIOSH investigate the suspect data pairs to determine how such pairs should be interpreted. To this end, NIOSH obtained the medical records of 24 randomly selected workers who exhibited examples of the suspect bioassay pairs. NIOSH concluded that when two bioassay pairs were present, the higher of the two pairs was consistently the correct result based on comparison with the hardcopy medical records. It is believed that the mechanism causing the erroneous bioassay pairs was likely the presence of multiple sets of units depending on which original hardcopy sources were used to compile the HIS_20 database.

As a result, NIOSH has recalculated the coworker model intake values by assuming that when paired bioassay results are present, the higher of the two is correct. Furthermore, unpaired results that provide numerical values with non-zero decimal results are assumed to be in error and are multiplied by 100 to obtain a urine result that is in the correct units. This second criterion was based on the fact that the HIS_20 database is in the units of µg/l, and no evidence exists that Fernald ever measured uranium urinalysis to a precision level of less than 1 µg/l. Although one would logically assume that an error involving incorrect units would result in a factor of 10^3 difference (i.e., a result in the units of mg/l incorrectly input as µg/l), SC&A notes that the observed suspect bioassay pairs were consistently a factor of 10^2 different and not 10^3.

Therefore, SC&A agrees with the suggested corrective approach proposed by NIOSH, as it is a claimant favorable approach and supported by actual examination of hardcopy records. NIOSH 2017b notes that these methods have already been adopted and incorporated into the calculations

present in Attachment C of NIOSH 2017a. **Therefore SC&A recommends that Finding 2 be closed.**

Observation 1 noted that SC&A was not able to recreate the urinary excretion rates reported by NIOSH for at least some years. SC&A and NIOSH exchanged calculation files to discover the source of the discrepancy. On August 3, 2016, NIOSH responded that the source of the discrepancy for some years was based on the specific calculation methods used by SC&A. SC&A had used the regression on order statistics (ROS) method outlined in ORAUT-PROC-0095, Revision 00, *Generating Summary Statistics for Coworker Bioassay Data* (NIOSH 2006). NIOSH clarified that coworker datasets that contain multiple left-censoring levels are better approximated using the ROS methodology described in ORAUT-RPRT-0053 (NIOSH 2014b). SC&A has reviewed the response and associated documentation and accepts NIOSH's clarification on how certain annual excretion data points were calculated. **Therefore, SC&A recommends Observation 1 be closed.**

Observation 2 simply pointed out that the use of the time-weighted one person–one sample (TWOPOS) method (instead of the traditional pooled approach) did not appreciably change the calculated median urinary excretion rates. However, the TWOPOS method did markedly reduce the variability in those calculated results. The reduction in variability was expected to be a characteristic of the new calculation methods. However, this observation was noted because the revision of OTIB-0078 using the TWOPOS approach was one of the first coworker models to implement the new methodology. In its response, NIOSH agreed with the observation as well as the mechanism behind it. **Therefore, SC&A recommends Observation 2 be closed.**

Observations 4 and 5 describe information that was contained in the "comments column" of the HIS_20 database. In the case of Observation 4, often a censored urinalysis value in the "results column" was coupled with a much lower value (likely the actual measurement value) in the comments column. Also, approximately 300 database entries contained comments such as "pre-employment," "re-employment," or "invalid" (Observation 5). These types of samples should not have been included in coworker assessment.

In its response, NIOSH noted that the comments section had not been used in the formulation of the OTIB-0078 coworker intakes; however, in future revisions of the coworker methodology relevant comments would be taken into account. It is not clear from the text of Attachment C of NIOSH 2017a whether these comments were incorporated into the newly derived coworker intakes. In fact, Attachment C reports the same number of total samples used in the coworker model as previously seen in OTIB-0078. Therefore, it seems unlikely that the inappropriate samples identified in Observation 5 were removed. Therefore, SC&A recommends placing these observations in abeyance pending confirmation from NIOSH that these adjustments were actually made in the recalculated intakes presented in NIOSH 2017a.

The final observation (Observation 6) discusses additional intake information that is often provided with each HIS_20 urinalysis result. This information includes designations of the intake pathway (inhalation or ingestion) and solubility type of the contaminant. NIOSH responded that there is little information available about how the designations of intake pathway and solubility type were reached in the original database. NIOSH notes that in the absence of reliable information on intake pathway, inhalation is the default assumption when evaluating bioassay

data. Furthermore, because information is also lacking about the solubility type of the inhaled contaminants, NIOSH calculates intakes for all applicable solubility types and assigns the most favorable type to the claimant. SC&A agrees with this approach, given the absence of information, and thus recommends that Observation 6 be closed.

SC&A Recommendation: Given the previous discussion, SC&A recommends that OTIB-0078 Finding 1 and Observations 3–5 be put "in abeyance" pending further clarification and/or confirmation from NIOSH that those items have been addressed and implemented. SC&A recommends that Finding 2 as well as Observations 1, 2, and 6 be closed based on NIOSH's response and/or adjustments made to the derived coworker model values.

2.6 UNMONITORED INTERNAL DOSE TO THORIUM AND THORON

On June 24, 2014, NIOSH transmitted a white paper, *Fernald Dose Reconstruction Methodology for the Post Special Exposure Cohort (SEC) Period, 1979–2006*, Revision 2 (NIOSH 2014a), which contains the proposed dose reconstruction methods for assigning internal thorium doses to unmonitored workers.[2] Subsequent to this, SC&A was tasked with reviewing the white paper to assess whether the proposed methods represent a plausible, sufficiently accurate, and claimant-favorable approach to assigning coworker intakes. The contents of NIOSH 2014a were also presented and discussed during the Fernald WG meeting on September 3, 2014 (ABRWH 2014a), which facilitated preliminary points of clarification regarding the coworker model. SC&A presented its review of NIOSH 2014a during the December 4, 2014, WG meeting (ABRWH 2014b).

Application of unmonitored thorium doses can be effectively split into two periods: 1979–1989 and 1990–1994. The former period utilizes in vivo monitoring data, which measured the thorium daughter products actinium-228 and lead-212 in order to develop unmonitored coworker intakes. The latter period utilizes a fraction of the derived air concentration (DAC) for assignment of thorium doses. Specifically, the method assigns 10% of the Class W DAC value to unmonitored workers (5×10^{-13} microcurie per milliliter [µCi/ml]). Each separate period and SC&A's review findings are discussed in the sections below.

2.6.1 Reconstruction of Unmonitored Thorium Doses (1979–1989)

SC&A's 2014d review identified three findings that were specific to the proposed dose reconstruction methods for thorium in the 1979–1989 period. Findings 1–3 all relate to the practical implementation of the proposed thorium coworker intakes. Specifically, Finding 1 noted that the majority of thorium-related activities were associated with re-drumming and repackaging activities; however, there was evidence to suggest that small-scale handling and production occurred after 1979. The workers who may have been involved in either thorium activity are not currently known; thus, it appears appropriate to assign unmonitored thorium dose to all workers.

Finding 2 discusses the fact that the in vivo monitoring program was not focused on thorium operations but rather the significantly more prevalent uranium operations at the Feed Materials

[2] Coworker dose assessment is only proposed for 1979–1994 in NIOSH 2014a; after this time, only monitored worker doses are reconstructed.

Production Center. Because the monitoring program was not necessarily focused on actual thorium operations (and therefore exposure potential), SC&A recommended that the 95th percentile be assigned to assure that the assigned doses to unmonitored workers who might have been exposed to thorium are sufficiently bounded.

Finding 3 noted the wide variety of job types and locations identified among claimants who had not been identified as a "thorium worker" in NIOSH 2014a but who indicated exposure to thorium in their computer-aided telephone interview. Because there is no plausible method currently available to sufficiently identify which workers may have been exposed to thorium, it would be appropriate to assign unmonitored intakes to the entire population of potential workers. Or conversely, specific irrefutable evidence should be identified and discussed if unmonitored thorium intakes are deemed inappropriate to assign to a given claimant. The pertinent section of the TBD regarding the assignment of thorium intakes during the period from 1979 through 1989 states the following:

> *Thorium coworker doses are assigned to all unmonitored workers, unless there is a reason why they should be excluded (e.g., a secretary or administrative individual who worked only in nonradiological areas). The 95th-percentile intake rate, with a constant distribution, is assigned to those with the highest potential for exposure. Workers with a baseline thorium fecal sample are included in this group, as well as subcontractors from IT Corporation working during 1988 and 1989. All others are assigned the 50th-percentile intake rate with a lognormal distribution.* [NIOSH 2017a, Section 5.5.2.3.1]

The TBD language instructing dose reconstructors to assign unmonitored coworker intakes to the entire worker population satisfies SC&A's concerns as described in Findings 1 and 3. Therefore, SC&A recommends closure of these findings. However, the language appears to suggest that the 95th percentile be assigned to "*those with the highest potential*" and then notes that workers with baseline fecal sampling for thorium and subcontractors from IT Corporation during the years 1988 and 1989 would qualify. It is not clear to SC&A whether the list of candidates to receive the 95th percentile is exhaustive or merely illustrative.

As noted in Finding 2, the monitoring program for thorium was not focused on thorium work occurring at the site but rather uranium work. Given this characteristic of the monitoring program, as well as the inability to identify which workers were potentially exposed to thorium and not monitored, SC&A maintains its recommendation that the 95th percentile be assigned to all claimants who would be considered "full-time radiological workers." This would appear to be consistent with guidance provided in Neton 2015 (Section 3.2):

> *For workers that are considered to have worked in environments with a potential for elevated exposure, the 95th percentile of the distribution should be used as an upper bound of their exposure during the modeled time period. Although it could be argued that the job categories that fall under this criterion should be listed, any attempt to do so might be artificially restrictive. For workers who were less likely to be highly exposed and/or were intermittently exposed in the workplace, the full distribution (i.e., the geometric mean and its associated standard*

> *distribution if a lognormal fit is used) should be used as representative of their potential for exposure during the modeled period.*

In the case of Fernald, it is not possible to know which radiological workers actually performed thorium-related work and thus would have the potential for higher exposures. Given this site characteristic, it would seem prudent to put emphasis on the Neton 2015 instructions concerning assignment of the full distribution. Namely that it should be assigned to workers who were "intermittently exposed in the workplace." This is also consistent with coworker modeling approaches taken at other sites, such as Simonds Saw and Steel.[3] SC&A acknowledges that such policy decisions about the level of dose assignment are ultimately subjective and site specific.

SC&A Recommendation: SC&A recommends that Finding 2 of SC&A 2014d remain "in progress" pending WG discussion as to the appropriateness of assigning the 95th percentile versus the full distribution of coworker intakes to claimants considered "radiological workers." As discussed in the previous section, SC&A recommends that Findings 1 and 3 be closed.

2.6.2 Reconstruction of Unmonitored Thorium Doses (1990–1994)

For the latter period in which unmonitored thorium coworker dose was evaluated, the SC&A 2014d review produced two additional findings (Findings 4 and 5). Finding 4 noted that NIOSH had selected the DAC value for solubility Class W for assignment as unmonitored intake. SC&A noted that the Class Y DAC for thorium was a factor of 2 higher (1×10^{-12} µCi/ml). NIOSH provides the following justification in the revised TBD (NIOSH 2017a, page 55):

> *Airborne areas would have been controlled to the lower Class W DAC. It is* ***standard industry practice*** *for the lowest DAC value to be used because, for a given air concentration, this results in a higher exposure in DAC-hours.*
> [emphasis added]

SC&A does not find any technical issues with NIOSH's position; however, it is often desirable to obtain site-specific evidence and information to verify that the industry standards were in practice. Therefore, it would be beneficial to obtain documentation from Fernald that the lower DAC value was always utilized during relevant thorium activities. Absent specific information to scientifically justify one assumed value over another, it is generally accepted to use the more claimant favorable approach under the auspices of the Energy Employees Occupational Illness Compensation Program. However, when such evidence does exist, the value that provides the greater scientific merit is clearly appropriate.

Finally, Finding 5 found that for the period 1990–1994 NIOSH 2014a had stipulated that thorium exposures should only be applied if the claimant had submitted a pre-job baseline fecal sample for thorium. Similar to Finding 1 and 3 in the previous section, SC&A recommended that the

[3] Section 3.3 of the Simonds Saw and Steel TBD states (NIOSH 2014c): "*The 95th-percentile intake rates in Table 3-13 should be applied to all Simonds mill workers, any other worker whose job could have involved work in or around the rolling mills or forge shop areas, and workers whose job is unknown. Workers whose job would not have required work in those areas (i.e., office workers) should be assigned the median intake rate to allow for being occasionally exposed in the general area of uranium processing areas.*"

assignment of unmonitored thorium intakes be expanded to all radiological workers unless clear and convincing evidence exists that thorium exposure could not have occurred. The original language indicating baseline fecal sampling as a prerequisite to the assignment of thorium intakes has not been included in the revised TBD instructions (see Section 5.5.2.3.2 of NIOSH 2017a). Therefore, SC&A assumes that unmonitored thorium intakes will be assigned in a manner consistent with the previous period (1979–1989), in which intakes are assigned unless specific information exists that the claimant could not have been exposed (i.e., not a radiological worker).

SC&A Recommendation: SC&A recommends that clarification, by way of additional site-specific documentation or justification, be provided to assure that use of the lower Class W DAC value is more scientifically appropriate than the higher Class Y DAC value (Finding 4). Regarding Finding 5, SC&A requests confirmation that unmonitored thorium exposures in the 1990–1994 timeframe will be applied to all potentially exposed workers and only withheld if clear evidence exists that the claimant was not exposed.

2.6.3 Reconstruction of Thoron Doses

As presented in SC&A's report 2014d and described in NIOSH 2014a, exposures to radon-220 (Rn-220) and associated daughters (also known as thoron) are derived based on characterizing the source term (by weight) of thorium in specific buildings, establishing the release fractions for Rn-220 in stored material as well as materials in process, and finally converting it to exposure using an assumed volume of respirable air in each facility.

Table F-5 of NIOSH 2014a gives the summary of thoron exposure estimates for various time periods. SC&A reviewed the thoron exposure estimates and the underlying assumptions used in their calculation. Section 9.0 of SCA 2014d discusses each of the assumptions and identifies two findings:

> ***Finding 6:*** *The underlying assumptions employed in NIOSH 2014a to reconstruct doses to thoron are not well established or referenced. The assumptions concerning thorium source term inventory, release fraction, equilibrium factor, occupancy time, and specific activity of thoron must be thoroughly defined based on credible documentation and site specific records.*
>
> ***Finding 7:*** *It is necessary that NIOSH evaluate the thoron/thoron daughters' exposures due to Ra-228. Independent of the time assumed after separation, it is necessary to evaluate if workers could have worked in areas where Ra-228 was handled or stored and consider the associated thoron exposures. As stated on page 105 of NIOSH 2014a, Ra-228 has a half–life long enough to permit its presence in the workplace for years independent of the original parent isotope (Th-232).*

In Attachment B of NIOSH 2017a, NIOSH provides an analysis of potential thoron exposures and discusses SC&A's concerns from SCA 2014d. SC&A believes it would be better to have an interactive discussion with the entire WG, rather than attempt a lengthy response in this report.

SC&A Recommendation: SC&A suggests a WG discussion pertaining to assumptions employed to reconstruct coworker thoron (Finding 6) and thoron/thoron daughters' exposures due to Ra-228 (Finding 7).

3.0 SUMMARY OF RECOMMENDATIONS

Table 3-1 contains a list of the actionable issues and SC&A's recommendations based on our review ORAUT-TKBS-00170-5, Revision 03.

Table 3-1. SC&A Recommendations Summary

Doc	No	Finding Text	SC&A Recommendation
TBD	7	The TBD does not specify a method for estimating doses in the raffinate streams, which are uranium poor, from ore processing in Plant 2/3. These doses may be very difficult to calculate, especially for high-grade ores, notably pitchblende ore from Congo.	**In progress**
TBD	8	Workers who may have worked with raffinates may be missed by the protocol specified in Volume 5 of the TBD. The guidelines for determining which workers were exposed to raffinate dusts are too restrictive and place far too great a reliance on completeness of records for job assignments, or in the alternative, place the burden of proof on the claimant. They have not been adequately justified by measurements and are not claimant favorable.	**In progress**
TBD	9	The data on trace contaminants in RU in the Fernald TBD are incomplete and appear to be incorrect. Different official documents have very different values for various aspects of RU data, including production and contamination. The contradictions have not been sorted out in the TBD.	**In progress**
TBD	10	The radionuclide list for RU in the TBD is incomplete. Furthermore, the concentrations of trace radionuclides in the raffinates, which are much higher than those in the feed material, are not adequately discussed.	**Close**
TBD	11	The suggested approach for RU dose estimation in the TBD is claimant favorable for many RU workers, but not claimant favorable for others and for some periods; it is not based on an evaluation of the available data.	**In progress**
TBD	15	Ingestion doses are not considered in the TBD.	**Close**
TBD	29	Occupational internal exposure to radon is estimated based on just two radon data points from 1953. This is an inadequate basis to reconstruct occupational radon dose.	**Close**
SEC P	3	Default concentrations (on U mass basis) of Pu-239, Np-237, and other isotopes associated with RU at Fernald may not be bounding for some classes of worker activities, buildings, and time periods.	**In progress**
OTIB-78	1	Although claimant favorable, the censoring of negative and zero bioassay results at the minimum observed positive value in a given year is inconsistent with the guidance provided in ORAUT-RPRT-0053, Revision 02, *Analysis of Stratified Coworker Datasets* (NIOSH 2014b), which specifies that all negative bioassay values be censored at zero. Note that the treatment of negative, zero, and results less than the MDA is an ongoing topic of discussion with the SEC Issues Work Group.	**In abeyance**
OTIB-78	2	NIOSH should closely examine questionable bioassay pairs that demonstrate differences of exactly two orders of magnitude on the same day for the same worker to assure that all of the numerical results used in OTIB-0078 accurately reflect the daily excretion rates for monitored workers at Fernald and are being interpreted correctly.	**Close**
OTIB-78	Obs 1	SC&A was able to recreate the annual daily excretion rates reported in Table 2-3 of OTIB-0078 with a reasonable degree of accuracy for most years. However, SC&A was not able to recreate the values reported for the years 1986–1997.	**Close**

Doc	No	Finding Text	SC&A Recommendation
OTIB-78	Obs 2	A comparison of the median urinary excretion rates derived in Revision 03 to OTIB-0078 (using the TWOPOS method) with the excretion rates calculated in Revision 01 to OTIB-0078 (using the pooled sample approach) showed very little difference. However, as expected, the use of TWOPOS methods results in a significant reduction in the variability of the derived distributions, and thus excretion rates at the 84th percentile were markedly lower using the TWOPOS method.	**Close**
OTIB-78	Obs 3	Sample results that were below the detection limit were not reported in a consistent fashion in the HIS_20 ORAU database. NIOSH has elected to treat negative and zero results by censoring the value at the lowest observed positive result by year. This approach is claimant favorable compared to using the negative and zero values as is although not consistent with the methodology in ORAUT-RPRT-0053 (see Finding 1).	**In abeyance**
OTIB-78	Obs 4	NIOSH appears to have used reported values at the MDA/control limit in situations where a lower numerical result was provided in the comments section of the bioassay entry. This is a claimant favorable interpretation of these records.	**In abeyance**
OTIB-78	Obs 5	SC&A observed 313 sample entries that should likely have been removed from the coworker model due to comments indicating the sample was an invalid result or the sample was for pre-employment/re-employment purposes. Given the relatively small incidence of such samples, the cumulative effect of excluding those results is likely to be insignificant.	**In abeyance**
OTIB-78	Obs 6	OTIB-0078 would benefit from a discussion of the additional intake information (intake pathway and solubility type) available in the HIS_20 ORAU database. Neither the pedigree and accuracy of such indicators nor whether appropriate adjustments to the intake model may be warranted are known at this time.	**Close**
SCA 2014d	1	While it appears that the majority of the thorium exposure potential at Fernald in the post-SEC period was related to redrumming and repackaging activities, some evidence exists that small-scale handling and possibly production may have occurred after 1979. Given that it is currently infeasible to identify which workers were involved in these operations and potentially exposed, and by extension whether those workers were properly monitored, NIOSH should assign unmonitored thorium intakes for all workers who may have entered radiological areas and been exposed to thorium materials.	**Close**
SCA 2014d	2	Given that the monitoring program does not appear to be directly focused on areas where thorium exposure potential existed, coupled with the inability to effectively identify which workers may have handled thorium materials, NIOSH should instruct the dose reconstructors to assign the 95th percentile coworker intake value to all unmonitored claimants who may have been directly involved in thorium operations.	**In progress**
SCA 2014d	3	Given the broad work locations and duties contained among worker job types not currently defined as a thorium worker in NIOSH 2014a, NIOSH should provide explicit instructions to the dose reconstructor that thorium coworker intakes should be assigned unless sufficient evidence exists that the claimant did not enter radiological areas where thorium exposure potential may have existed.	**Close**
SCA 2014d	4	Unless sufficient evidence exists that thorium exposure potential at Fernald was restricted to solubility Class W, NIOSH should consider using the more conservative and claimant favorable DAC value for solubility Class Y.	**Discussion**
SCA 2014d	5	NIOSH should not restrict the assignment of thorium intakes to workers who submitted pre-employment fecal samples, but rather assign intakes based on the potential for radiological exposure.	**Discussion**
SCA 2014d	6	The underlying assumptions employed in NIOSH 2014a to reconstruct doses to thoron appear to be arbitrary and are not well established or referenced. The assumptions concerning thorium source term inventory, release fraction, equilibrium factor, occupancy time, and specific activity of thoron should be more carefully defined based on credible documentation and site-specific records	**Discussion**

Doc	No	Finding Text	SC&A Recommendation
SCA 2014d	7	It is necessary that NIOSH evaluate the thoron/thoron daughters' exposures due to Ra-228. Independent of the time assumed after separation, it is necessary to evaluate whether workers could have worked in areas where Ra-228 was handled or stored and consider the associated thoron exposures. As stated on page 105 of NIOSH 2014a, Ra-228 has a half–life long enough to permit its presence in the workplace for years independent of the original parent isotope (Th-232).	**Discussion**

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