Draft Report

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

ADVISORY BOARD ON RADIATION AND WORKER HEALTH

SC&A REVIEW OF NIOSH RESPONSES TO SC&A COMMENTS ON ORAUT-OTIB-0054, REV. 1:

FISSION AND ACTIVATION PRODUCT ASSIGNMENT FOR INTERNAL DOSE-RELATED GROSS BETA AND GROSS GAMMA ANALYSES

Contract No. 211-2014-58081
SCA-TR-PR2014-0084

Prepared by

Stephen Ostrow
John Mauro
Ron Buchanan
SC&A, Inc.
1608 Spring Hill Road, Suite 400
Vienna, VA 22182

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SC&A, Inc.: ***Technical Support for the Advisory Board on Radiation and Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-PR2014-0084 Effective Date: Draft – April 10, 2014 Revision No: 0 – Draft
SC&A Review of NIOSH Responses to SC&A Comments on ORAUT-OTIB-0054, Rev. 1: ***Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses***	Supersedes: N/A
Task Manager: _____ Date: _____ Stephen L. Ostrow, PhD Project Manager: _____ Date: _____ John Stiver, MS, CHP	Reviewers: John Stiver John Mauro Stephen Ostrow

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	04/10/2014	Initial issue.

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
ATR	Advanced Test Reactor
Bq	Becquerel
BRS	Board Review System
Ci	Curie
d	day
DCF	dose conversion factor
DOE	U.S. Department of Energy
FFTF	Fast Flux Test Facility
HEPA	high efficiency particulate air
ICD	International Classification of Diseases
IMBA	Integrated Modules for Bioassay Analysis
INL	Idaho National Laboratory
IREP	Interactive RadioEpidemiological Program
MFAP	mixed fission and activation products
µCi	microcurie
ml	milliliter
NIF	normalized intake fraction
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
ORIGEN	Oak Ridge Isotope Generator (computer code)
ORNL	Oak Ridge National Laboratory
OTIB	ORAUT Technical Information Bulletin
pCi	picocurie
SC&A	S. Cohen and Associates (SC&A, Inc.)
SRS	Savannah River Site
TRIGA	Training Research and Isotope Production, General Atomics
y	year

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EXECUTIVE SUMMARY

Note: While SC&A was in the process of reviewing NIOSH's responses to SC&A's comments on Rev. 1 of ORAUT-OTIB-0054 (ORAUT 2013), NIOSH issued Rev. 2 on March 4, 2014 (ORAUT 2014). The Publication Record for Rev. 2 states: "Revision initiated to correct an error with the Pm-147 intake fractions in Tables 7-3b and 7-3c. The values had mistakenly been entered as zeros. No changes occurred as a result of formal internal review." SC&A checked that NIOSH did indeed make that correction in Rev. 2 of those two tables, for the ATR 2 and ATR 3 reactors respectively.

Based on a cursory comparison of Rev. 1 and Rev.2, SC&A did not notice any other changes to the documents. In addition, SC&A would not expect the Pm-147 correction to have a material effect on dose reconstructions. However, SC&A recommends that NIOSH make a statement to that effect as part of the issues resolution process, and if true, then the review of Rev. 1 in this document applies as well to Rev. 2.

Frequently, air-sampling or urinalysis data on worker exposure to mixed fission and activation products associated with nuclear reactors or nuclear fuel are available only in the form of gross beta or gross gamma activity unattributed to specific radionuclides. This is particularly true for exposures during the early decades of the U.S. nuclear program. For those cases, ORAUT-OTIB-0054, *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses* (hereafter referred to as "the OTIB" or "OTIB-0054") provides guidance and a standard approach to the dose reconstructor on how to assign radionuclide-specific intakes to exposed workers.

SC&A reviewed Rev. 0 of the OTIB (ORAUT 2007) in 2008 (SC&A 2008) and identified 26 issues, some of which were subsequently resolved through work of the Advisory Board on Radiation and Worker Health (ABRWH) Subcommittee on Procedures Review, NIOSH, and SC&A. The technical basis of the OTIB was substantially revised from Rev. 0 to Rev. 1 (ORAUT 2013), leading the Subcommittee at its July 18, 2013, meeting to authorize SC&A to perform a full *de novo* review of Rev.1. SC&A presented its comprehensive technical review of Rev. 1 in its November 2013 report, SC&A 2013. That review produced 10 findings on Rev. 1 of the OTIB, which NIOSH responded to on February 4, 2014, via entries to the online Board Review System (BRS).

SC&A's detailed review of Rev.1 of the OTIB is presented in SC&A 2013, which should be consulted in order to gain an appreciation of the background of each finding. That review produced 10 findings, each listed in Table 1 along with accompanying NIOSH BRS responses of February 4, 2014. Section 1 of this report presents SC&A's subsequent review of NIOSH's BRS responses to SC&A's findings. The results of this latest review are also summarized in Table 1. It should be noted that two sets of finding numbers appear. The *de novo* OTIB Rev. 1 review of SC&A 2013 labeled its findings 1–10, but since the BRS already listed 26 findings against Rev. 0, the 10 new findings are numbered 27–36.

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Table 1. Findings on Rev. 1 of the OTIB, NIOSH BRS Entries, and SC&A Responses

Finding: BRS (SC&A 2013) Numbering	Finding Summary,[a] NIOSH BRS Entry,[b] SC&A Response[c]
27 (1)	SC&A Finding: SC&A is not able to evaluate the appropriateness of the input parameters used for the ORIGEN2 runs since they are not specified or references cited in the OTIB. NIOSH BRS Entry: The ORIGEN2 runs and the process of down-selecting to four representative reactors were not affected by the revision. A separate report is planned that will document the reactor modeling process in detail. SC&A Response: SC&A will review the NIOSH reactor modeling report when it is available and recommends that the status of this finding remain *In Progress* pending that review.
28 (2)	SC&A Finding: The OTIB does not provide sufficient information to allow evaluation of its down-select from the initial seven to the final four representative reactors chosen. NIOSH BRS Entry: See response to Rev. 1, Finding 1. SC&A Response: SC&A will review the NIOSH reactor modeling report when it is available and recommends that the status of this finding remain In Progress pending that review.
29 (3)	SC&A Finding: While Rev. 0 of the OTIB (Section 5.2) provides extensive discussions of the ORIGEN2 runs for each reactor, Rev. 1 does not for the ORIGEN-S runs. For each of the nine representative reactor cases, the OTIB (Table 5-2) specifies the specific power, irradiation time, and burnup, and includes a basis (e.g., "maximum burnup at nominal power" for ATR 1), but does not say how the values were selected or cite any reference; Rev. 0 made extensive use, for example, of the DOE report, *Source Term Estimates for DOE Spent Nuclear Fuels*, DOE/SNF/REP-078, Rev. 0, March 2003 (DOE 2003). SC&A cannot fully evaluate the appropriateness of the values chosen for each case without such information. NIOSH BRS Entry: See response to Rev. 1, Finding 1. SC&A Response: SC&A will review the NIOSH reactor modeling report when it is available and recommends that the status of this finding remain *In Progress* pending that review.
30 (4)	SC&A Finding: SC&A notes that Table 5-1 of the OTIB lists both aluminum and stainless steel-clad TRIGA reactors as belonging to the initial set of seven reactors. However, Table 5-2, which lists the four reactors chosen as references, as well as the accompanying text, do not indicate which cladding was assumed for the TRIGA reactor. The OTIB also does not indicate what fuel enrichment was chosen, give a source for the specific power or the chosen burnups, or provide justification for its assumptions. NIOSH BRS Entry: The cladding type (stainless steel) can be specified in Table 5-2. See response to Rev. 1, Finding 1. SC&A Response: SC&A will review the NIOSH reactor modeling report when it is available and recommends that the status of this finding remain *In Progress* pending that review.

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Table 1. Findings on Rev. 1 of the OTIB, NIOSH BRS Entries, and SC&A Responses

Finding: BRS (SC&A 2013) Numbering	Finding Summary,[a] NIOSH BRS Entry,[b] SC&A Response[c]
31 (5)	SC&A Finding: In selecting release fractions for exposures to airborne radionuclides associated with reactor operations, the OTIB starts with the fuel inventory. However, it might have been more appropriate to use the mix of radionuclides in the gas gap or primary coolant as the starting point for assigning the isotopic composition in urine samples. Also, if a worker was involved in handling waste streams, such as ion exchange resins or HEPA or charcoal filters, using the isotopic mix in fuel as the starting point might not be appropriate and might lead to non-claimant-favorable results. These issues should be addressed in the OTIB. NIOSH BRS Entry: Limiting the radionuclides to just those in the gap or coolant would not be appropriate for fuel separations or other work activities and would likely reduce assigned doses. The same is true for filtration media: limiting the source term to just the volatile and semi-volatile species would likely reduce assigned doses. Gross gamma and gross gamma assays for MFAP are primarily seen for sites where large-scale fuel separations were performed, e.g., Hanford, INL, ORNL, and SRS. SC&A Response: SC&A (1) agrees with NIOSH's response with regard to preference of using reactor fuel radionuclide inventory rather than gas gap inventory as a starting point; (2) however, not knowing the organ of concern, SC&A questions whether the Normalized Intake Fractions (NIFs), as used to derive radionuclide intakes based on gross beta analysis of urine, will always result in a claimant-favorable outcome. This requires further discussion and SC&A recommends that this finding remain *In Progress*.
32 (6)	SC&A Finding: The use of effective dose conversion factors (i.e., DCFs that relate to effective whole-body dose) is appropriate for screening purposes if the objective of the OTIB was to reconstruct whole-body doses, but not necessarily claimant-favorable for organ doses. For example, a radionuclide that does not contribute significantly to the whole-body dose could be an important contributor to an organ dose and might be eliminated. For certain reactor scenarios, some radionuclides that were not present in Table E contribute to the intake in a significant way and can deliver important contributions to organ doses. The OTIB would benefit from some discussion of this matter. NIOSH BRS Entry: SC&A may have misunderstood the process outlined in OTIB-54 revision 1. The list of nuclides in Table D-1 was not created using effective dose conversion factors as they report. The list was created using committed organ doses. The list created in Table D-1 was later reduced using effective dose as recommended by SC&A's review of revision 0 of OTIB-54 (Comment 13 of the March 2008 report). SC&A Response: SC&A agrees with NIOSH and recommends that the finding be *Closed*.

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Table 1. Findings on Rev. 1 of the OTIB, NIOSH BRS Entries, and SC&A Responses

Finding: BRS (SC&A 2013) Numbering	Finding Summary,[a] NIOSH BRS Entry,[b] SC&A Response[c]
33 (7)	SC&A Finding: Intakes and organ doses should be calculated using the same set of radionuclides as used to derive the contributions to the total beta excretion rate results. NIOSH BRS Entry: It is desirable to limit the number of associated radionuclides considered in the organ dose calculations to reduce the computational burden on the dose reconstructors. As discussed under Comment 6 above alternative methods for assigning the dose contributions from associated radionuclides are being evaluated. SC&A Response: SC&A agrees with NIOSH because, by eliminating the less important radionuclides, the release fractions of the more important radionuclides are increased. SC&A recommends that the finding be *Closed*.
34 (8)	SC&A Finding: The OTIB explains that it was recognized that some of the methods used to determine the beta/gamma concentration of fission and activation products in urine would miss certain radionuclides, such as radioiodines. The OTIB claims that this is not a problem because the isotopic assignments of intake are based on the predicted relative concentrations of 17 radionuclides in air. Hence, these radionuclides are not missed when deriving doses. This seems reasonable, except if a large fraction of the activity is lost during the analysis of the urine samples. This, of course, would result in an underestimate of the actual gross beta/gamma composition of the urine, which would underestimate the radionuclide intake. The OTIB states that this issue was taken into consideration, and it was found to be important at the Savannah River Site (SRS). For this reason, a separate protocol is used in the SRS site profile. It is not apparent, however, how the dose reconstructor deals with situations where the airborne mix of radionuclides that might be associated with reactor operations or maintenance bears little resemblance to the mix of radionuclides in the fuel. NIOSH BRS Entry: We never said radionuclides would be missed, rather we made the claimant-favorable assumption that iodines were not present in the urine. The OTIB accounts for chemical processing of the samples, as appropriate, and is intended for bioassays collected for monitoring for intakes of mixed fission and activation products (i.e., those associated with operations involving such source terms). The question of the assigned excretion understating the corresponding intake isn't specific to OTIB-0054. Material lost in processing should be accounted for in the chemical recovery or other corrections applied by the counting lab. The chemical recoveries associated with a given separations procedure are immaterial unless they differ significantly for different radioelements. For gross beta counting the chemistry used, if any, is largely irrelevant since most of the activity is from radiostrontium (for any reactor or decay time). SRS was treated individually because the gross gamma counts there were performed subsequent to chemical separations. OTIB-0054 only considers gross gamma assays for raw or minimally-processed samples. SC&A Response: However, the iodines and other radionuclides are taken into consideration based on the NIF as derived in the OTIB and presented in Table 7-3. Inspection of Table 7-3 reveals that I-131 is assigned a high NIF, indicating it is properly accounted for. SC&A agrees with NIOSH and recommends that the finding be *Closed*.

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Table 1. Findings on Rev. 1 of the OTIB, NIOSH BRS Entries, and SC&A Responses

Finding: BRS (SC&A 2013) Numbering	Finding Summary,[a] NIOSH BRS Entry,[b] SC&A Response[c]
35 (9)	SC&A Finding: The current OTIB workbook (Workbook 1.01) needs to be revised to match the current version of OTIB-0054 (Rev. 1), and then re-evaluated. NIOSH BRS Entry: A revised tool was released for dose reconstructions on November 22, 2013. SC&A Response: OTIB-0054 Workbook 1.2.0 correctly derives the intake values (except for Pm-147 for ATR-2 and ATR-3) when using Sr-90 or Cs-137 as the indicating radionuclide when used in conjunction with the *Urine Activity Fraction* function. However, the workbook appears to skip the step necessary to apply the activity ratio value (i.e., the fraction of the total measured activity that is due to Sr-90 or Cs-137) from Tables 7-4a or 7-4b in all other cases, resulting in the intake values being substantially too large. This program error will produce intake values that are too large in the output of the Workbook when using gross air concentration in all cases, and also when using urine data if the *Urine Activity Fraction* is not selected. Additionally, the current version of the Workbook (Ver. 1.2.0) needs updating to incorporate the Pm-147 values for ATR-2 and ATR-3 listed in Tables 7-3b and 7-3c of Rev. 2 of the OTIB. Hence, SC&A recommends that this finding remain *In Progress*.
36 (10)	SC&A Finding: Our primary concern with this OTIB is that although NIOSH developed a protocol that simplifies and likely overestimates the radionuclide intakes for individual workers, the protocol seems to be somewhat arbitrary when applied to a particular worker. In the process of developing the protocol, indicator radionuclides are used to derive intake values of the dosimetrically significant radionuclides **that do not necessarily relate to the real intakes and excretion rates for any given worker**. NIOSH does not show the degree of realism or conservatism built into the dose reconstruction for a given worker due to the scenario that was assumed by all other assumptions taken to derive the values in the tables presented in Section 7. The methods described in the OTIB will provide intakes and doses not necessarily correlated with the real ones. The differences between the intakes provided through the use of the document and the real ones are unknown and depend heavily on the scenario (periods of fuel irradiation and decay), the reactor type, and detection methods. It could be argued that as long as the protocol is scientifically valid and claimant favorable for a given worker, the approach is consistent with the letter and intent of the rule. However, we can envision a situation where two workers are assigned a dose using the OTIB, where in one case, the protocol is extremely claimant favorable and the worker is compensated, and in the other case, the protocol is less claimant favorable and the claim is denied. The OTIB would benefit from a discussion of this particular concern. NIOSH BRS Entry: The goal was to develop a process that had little chance of underestimating a worker's dose. It was never intended to be precise. Additional discussion of that point can be added, as requested. SC&A Response: SC&A accepts that the basic approach used in the OTIB is claimant favorable, with due consideration of the question raised under Finding 31 (5), but believes that more discussion of the overall claimant-favorability of the strategy employed in the OTIB is warranted. Hence, SC&A recommends that this finding remain *In Progress*.

Notes
(a) SC&A 2013
(b) NIOSH BRS entries of February 4, 2014
(c) See Section 1.0 of this report for elaboration

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1.0 EVALUATION OF NIOSH RESPONSES TO SC&A 2013 FINDINGS

NIOSH responded to SC&A's 10 findings of SC&A 2013 via the BRS entries of February 4, 2014. The following subsections present SC&A's subsequent re-evaluation of the issues.

1.1 FINDINGS 27–30 (1–4)

These findings are all concerned with reactor modeling issues that SC&A identified in Section 5 of the OTIB. NIOSH indicated in its February 4, 2014, BRS entries that it is preparing a reactor modeling report that will respond to these findings in detail. SC&A will review that report when it is available and recommends that the status of Findings 27–30 (1–4) remain In Progress pending that review.

1.2 FINDING 31 (5)

This finding concerns whether it is more appropriate when selecting release fractions for exposures to airborne radionuclides associated with reactor operations to start with the fuel inventory, as in the OTIB, or to start with the gas gap radionuclide inventory, as SC&A suggests. In order to investigate this issue and to identify any further, related concerns, SC&A went through the first example problem of the OTIB (Attachment H) by hand.

Table H-1 presents the results of the first step in an example analysis, indicating that, based upon actual gross beta bioassay results, ranging from 17 to 57 pCi/24 hours, the Sr-90 excretion rate ranged from 8 to 28.8 pCi/24 hours for 8 urine samples collected from July 23, 1964, to November 2, 1966. The conversion factor used to go from gross beta excretion rates to Sr-90 excretion rates is 0.471, taken from Table 7-2. That conversion factor is the urine activity fraction that is applied to Sr-90 for samples of urine collected from a worker, and is based on the following assumptions: (1) ATR-1 reactor fuel; (2) the worker was associated with waste management operations; (3) the decay time for the isotopes was one year (i.e., the time period the radionuclides decayed after removal from the reactor), and (4) the urine samples underwent major chemical processing to maximize the capture of Sr-90 and eliminate other important beta emitters, such as K-40, from the sample. Without actually performing the ORIGEN (Croff 1980) runs for the reference ATR-1 reactor, determining what the activity might be in waste streams, and then going through the radiochemistry associated with urine analysis, we found that the results appear to be reasonable if not bounding.

Using standard IMBA techniques, the estimated excretion rate for Sr-90 is used to estimate the intake rates for Sr-90 during the time period the samples were collected. It was assumed that the intake was for Type F uranium and the IMBA program derived an intake value of 76 pCi/day was obtained for the time period of January 28, 1960 through January 25, 1971. We accept this intake result on face value and agrees that Type F is the appropriate clearance category.

Given the derived Sr-90 intake rate, the intake rates of other potentially important radionuclides were derived using the ratios for one-year-old ATR-1 material provided in Table H-2, which, in turn, are based on Table 7-3a of the OTIB. This is a key step in the analysis that must be

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understood, as the process to derive the activity fractions in Tables 7-2 and 7-3a is quite complex. Accordingly, SC&A went through the process described in the OTIB in some detail.

The starting point of the investigation is Section 6.0, "Determination of Intake Fractions and the Dosimetrically Significant Radionuclides." For the purpose of this portion of the review, SC&A accepts the radionuclide mix of the ATR-1 fuel as derived using ORIGEN-S and the associated parameters delineated in Table 5-2, and also the decay times for the steps in the fuel cycle delineated in Table 5-3.

It is appropriate to note that in revisiting the OTIB, we now agree with NIOSH's response to our Finding 6 (BRS Finding 32). SC&A was incorrect in assuming that the effective dose was used for screening. NIOSH, also stated that it is using the committed organ doses for screening, which we believe is a scientifically sound screening strategy.

As explained in Section 6.1 of the OTIB, starting with the decayed radionuclide inventory data, derivation of the intake fractions begins by adding up the activity of the full list of radionuclides, and then removing the activity of certain radionuclides. The grounds for removal include short-lived radionuclides, noble gases, and radionuclides without dose conversion factors (DCFs) for committed organ dose, including those radionuclides that are inexorably associated with a relatively long-lived parent (e.g., Ba-137m). SC&A concurs with this screening step.

Given the revised list of radionuclides, each radionuclide is assigned a Normalized Intake Fraction (NIF) by:

- Multiplying each radionuclide available fuel activity (e.g., 10 Ci) by its release fraction (e.g., 0.01). This represents how much (e.g., 0.10 Ci) of a given radionuclide is available for intake.
- Summing up all the activities (e.g., total curies) available for intake (e.g., 0.1 Ci + …) and then dividing the individual available activity (e.g., 0.1 Ci) of a radionuclide by the total number of curies to obtain the NIF for each radionuclide.

This provides radionuclide ratios that can be used to assign intakes from all the radionuclides of interest if the intake of one of the radionuclides is known; i.e., by urine bioassay as listed in Tables 7-3a-i.

This strategy for creating a selected list of normalized release fractions is scientifically sound and the use of conservative release fractions of nonvolatile components (i.e., 0.01 instead of 0.001) would not impact the derivation of Tables 7-3a-i. However, looking at the last few paragraphs of Section 6.1 of the OTIB, we are not sure that using a conservative release fraction for some radionuclides would not negatively impact the relative weight of other radionuclides when deriving Tables 7-1a, 7-1b, and 7-2. For example, would not using a larger than normal release fraction for one radionuclide diminish the projected Sr-90 activity in a urine sample in Table 7-1a?

On face value, the use of 0.01 for all non-radioiodines seems to be claimant favorable, because many of those radionuclides actually have much lower volatility fractions on the order of 0.001. However, after applying these volatility fractions to the list of radionuclides, a new list of the activities of radionuclides is generated, where the activity of low volatility radionuclides, such as

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Co or Fe, are then overestimated because their volatility fractions are more likely to be 0.001. If SC&A understands the process correctly, overestimating the volatility factors for some radionuclides results in understating the relative contribution of the more volatile radionuclides that are assumed to comprise the gross beta activity in the urine, which, depending on the organ of concern, might not be claimant favorable.

In summary, SC&A (1) agrees with NIOSH's response with regard to preference of using reactor fuel radionuclide inventory rather than gas gap inventory as a starting point; (2) however, not knowing the organ of concern, SC&A questions whether the Normalized Intake Fractions (NIFs), as used to derive radionuclide intakes based on gross beta analysis of urine, will always result in a claimant-favorable outcome, and recommends that this finding remain In Progress pending an elaboration by NIOSH.

1.3 FINDING 32 (6)

This SC&A comment expressed concern that part of the screening process for eliminating inconsequential radionuclides for explicit consideration was the use of effective DCFs. As noted in the boxed comment in the Section 1.2 discussion of Finding 31 (5), NIOSH explained and the OTIB makes it clear that committed organ DCFs were used as part of the screening process. SC&A agrees with NIOSH and recommends this finding be Closed.

1.4 FINDING 33 (7)

This SC&A finding expressed concern that by screening out so many radionuclides, the reconstructed doses will be underestimated. NIOSH explained that, as part of the normalization process, by screening out the radionuclides that contribute very little to any of the organ doses, more weight is given to those radionuclides that could contribute significantly to any organ doses, and, therefore, is claimant favorable. SC&A agrees with this comment, because by eliminating the less important radionuclides, the release fractions of the more important radionuclides are increased. SC&A recommends this finding be Closed.

1.5 FINDING 34 (8)

This SC&A finding expressed concern that the methods used to quantify the gross beta activity in urine would remove the radioiodines from the urine sample and underestimate the gross beta activity. NIOSH's BRS response to this issue states that radioiodines, and perhaps other radionuclides as well, might not be counted in a gross beta analysis of urine. However, the iodines and other radionuclides are taken into consideration based on the NIF as derived in the OTIB and presented in Table 7-3. Inspection of Table 7-3 reveals that I-131 is assigned a high NIF, indicating it is properly accounted for. SC&A therefore agrees with NIOSH's response and recommends this finding be Closed.

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1.6 FINDING 35 (9)

1.6.1 Introduction

SC&A evaluated the OTIB-0054 Workbook 1.2.0 in conjunction with the current Rev. 2 version of the OTIB.[1] The sequence of the release of the OTIB and its related Workbook is as follows:

- 5/11/2007, OTIB-0054, Rev. 0
- 10/09/2007, OTIB-0054 Workbook, Ver. 1.01
- 11/19/2007, OTIB-0054, Rev. 0 PC-1
- 6/13/2013, OTIB-0054, Rev. 1
- 11/21/2013, OTIB-0054 Workbook, Ver. 1.2.0 – current version
- 3/06/2014, OTIB-0054, Rev. 2 – current version

To evaluate the current OTIB-0054 Workbook Ver. 1.2.0 (referred to as the Workbook), SC&A analyzed the three examples provided in Attachment H of the OTIB to verify the methodology and compatibility of the examples with the text and tables of the OTIB. SC&A then ran the intake calculations for these three examples using the Workbook. An example of the data input screen for the Workbook is shown in Figure 1.

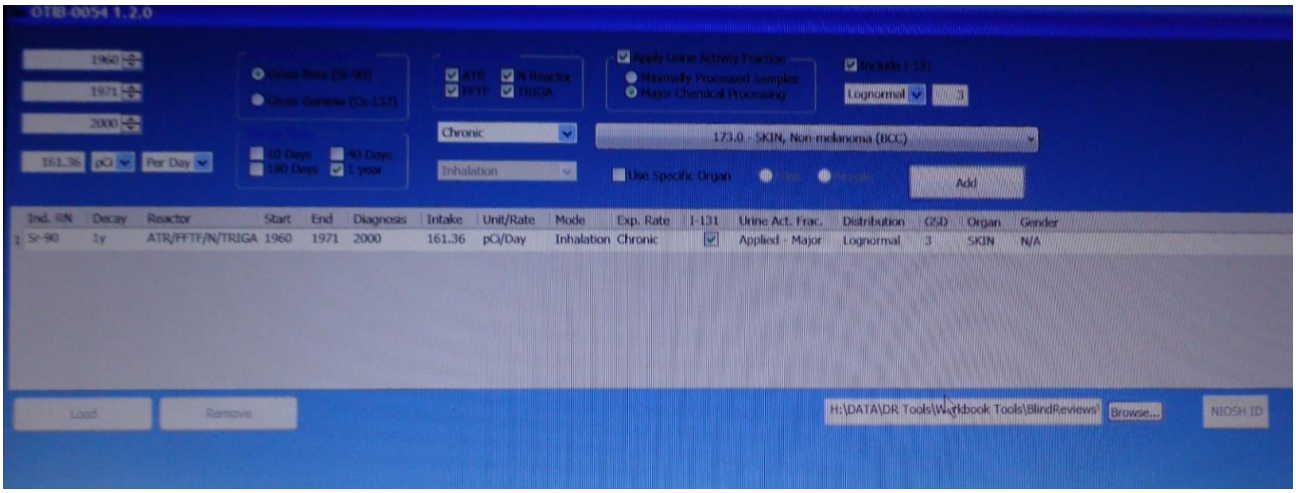

Figure 1. Example of OTIB-0054 Workbook Ver. 1.2.0 Data Input Screen

1.6.2 Operation of Workbook 1.2.0

Inputs

The input screen and operation of Workbook Ver. 1.2.0 is different than the older Ver. 1.01. Workbook Ver. 1.2.0 is located in the DR Tools folder and can only be accessed through the use of the DR Tools unique password. To illustrate the use of the newer version, a summary of its inputs and operations will be provided:

[1] SC&A reviewed Rev. 2 rather than Rev. 1 of the OTIB in this section; see Note section preceding the Executive Summary of this report.

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- As the copy of the screen above indicates, you are required to enter the exposure start year, the end year, and the year the cancer was diagnosed.
- Select if it is based on a Sr-90 beta or Cs-137 gamma as the indicator.
- Enter the intake value of the gross beta or gamma indicator (in any of the units provided).
- Select the decay time.
- Select the reactor group type(s).
- Select chronic or acute exposure.
- Select the amount of urine sample processing.
- Check if you want to include I-131 intakes.
- Select the ICD cancer code.
- Select the distribution function.
- Enter the case number.
- Select the location where the results will be saved

After these items are entered, you click on *ADD*. If you want to change any of these inputs, you must highlight the entire line, click *REMOVE*, and then start over.

Once you are satisfied that the entries are correct, you click on *Get Results*.

Computations

When the *Get Results* button is activated, the program goes through all the reactor types for the reactor group(s) you selected (ATR1, ATR2, ATR3, FFTF1, FFTF2, N1, N2, TRIGA1, TRIGA2), up to nine total. It then provides the output in the form of three Excel spreadsheets.

Output

The results are provided in three Excel spreadsheets, labeled *IREP, Summary*, and *Detail 1*. A brief summary of these outputs is as follows:

***IREP* –** This spreadsheet lists the standard IREP table data and annual doses from the reactor that provides for the largest dose for the organ of concern. It also provides the type of reactor, (e.g., ATR-2) that produced the largest dose. An Example of the *IREP* spreadsheet is provided in Appendix A of this section.

***Summary* –** This spreadsheet provides a summary of the input parameters used and the top reactor types that produced the largest doses for the organ of interest, along with the total dose derived for each of the reactor types. An Example of the *Summary* spreadsheet is provided in Appendix B of this section.

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Detail 1 – This spreadsheet provides the details for each radionuclide intake used in deriving the dose, along with a summary of the input parameters, the reactor type that produced the largest dose, solubility type, and annual doses. Note that the output results for the intake values are always converted to Bq/year regardless of the units used in the input; this cannot be changed. SC&A found that the wording in Column I of this spreadsheet does not appear to be applicable to this version; i.e., it states:

> *One column for every year Exposed, one row for every year of Latency*
> *Data in columns C to CE is equal to Data in column CF times the Intake (in Bq) for that year (row 89)*

However, there is no data Column CF, and the data in Row 89 is only for one of the many radionuclides analyzed. Apparently, this is a carryover from the older version of the workbook because it appears in that version and is only applicable there. An Example of the *Detail 1* spreadsheet is provided in Appendix C of this section.

1.6.3 SC&A's Evaluation

There are an enormous number of possible combinations of reactor types, decay times, sample processing, radionuclide indicators, and applicable radionuclides to test in this Workbook and compare them to values in OTIB-0054 (i.e., Tables 7-1a-b, 7-2, 7-3a-i, 7-4a-b). Therefore, SC&A found that an efficient way to evaluate the Workbook was to run it for the three examples of Attachment H of the OTIB and compare the details of the results from the Workbook to those hand-calculated and/or listed in the OTIB. This is summarized in the following examples.

Example #1

This example involved an intake period of [**redacted**] using gross beta urinalysis for a [**redacted**] worker; therefore, according to Table 5-3, a 1-year decay would be used. The bioassay urinalysis gross beta results listed in Table H-1 were used to derive a chronic intake of 161.36 pCi/d using the IMBA program (this corresponds to 76.0 pCi/d for ATR-1 as illustrated on page 67 of the OTIB, but the Workbook requires a gross beta input, which is 161.36 pCi/d, not the Sr-90 intake value of 76.0 pCi/d). Major processing of the bioassay samples was indicated; therefore, this would be selected during the input phase (corresponding to using Table 7-2 of the OTIB).

Entering these parameters into the Workbook provided the resulting three spreadsheets as previously described. The outputs of these spreadsheets were evaluated and compared to the results listed in the OTIB. SC&A condensed the output from the *Detail 1* spreadsheet and compared it to the values in Table H-2 of the OTIB, as illustrated in Table 2.

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Table 2. Comparison of Workbook Results to OTIB-0054 for Example #1

Isotope	Workbook Solu. & Intake (Bq/Yr)	Workbook pCi/day	OTIB-54 Table H-2 pCi/day	(WorkBk)/ (Table H-2)
Ce-141	Max(M)			
	4.66E+01	3.45E+00	3.45E+00	1.00
Ce-144	Max(M)			
	1.28E+04	9.50E+02	9.58E+02	0.99
Co-60	Max(S)			
	1.90E-01	1.41E-02	1.41E-02	1.00
Cs-134	F			
	5.67E+02	4.20E+01	4.20E+01	1.00
Cs-137	F			
	1.04E+03	7.68E+01	7.68E+01	1.00
Eu-154	M			
	2.29E+01	1.69E+00	1.69E+00	1.00
I-131	F			
	6.50E-08	4.81E-09	4.81E-09	1.00
Nb-95	Max(M)			
	4.19E+03	3.10E+02	3.10E+02	1.00
Pm-147	Max(M)			
	2.49E+03	1.84E+02	1.84E+02	1.00
Pr-143	Max(M)			
	1.07E-03	7.90E-05	7.90E-05	1.00
Ru-103	Max(F)			
	8.97E+01	6.63E+00	6.63E+00	1.00
Ru-106	Max(F)			
	9.42E+02	6.97E+01	6.97E+01	1.00
Sr-89	F			
	5.44E+02	4.02E+01	4.02E+01	1.00
Sr-90	F			
	1.03E+03	7.60E+01	7.60E+01	1.00
Y-90	Max(M)			
	1.03E+03	7.60E+01	7.60E+01	1.00
Y-91	Max(M)			
	1.26E+03	9.35E+01	9.35E+01	1.00
Zr-95	Max(F)			
	1.95E+03	1.44E+02	1.44E+02	1.00
	Total:	**2.07E+03**	**2.08E+03**	**1.00**
Input Parameters:	**ATR-1**	Sr-90 indictor	1 year decay	
		Input = 161.36 pCi/d	Gross beta	
			Major sample proc.	

As can be seen from this comparison, the Workbook duplicated the values in OTIB-0054 for Example #1 within rounding errors.

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Example #2

This example involved an intake period of [redacted] using gross beta urinalysis for a [redacted] worker; therefore, according to Table 5-3, a 10-day decay would be used. The bioassay urinalysis gross beta results listed in Table H-3 were used to derive a chronic intake of 164.0 pCi/d using the IMBA program (this corresponds to 164.0 pCi/d × 2.14E-2 = 3.51 pCi/d for ATR-1, as illustrated on page 69 of the OTIB, but the Workbook requires a gross beta input, not the Sr-90 intake value). Minor processing of the bioassay samples was indicated; therefore, this would be selected during the input phase (corresponding to using Table 7-1a of OTIB-0054).

Entering these parameters into the Workbook provided the resulting three spreadsheets as previously described. Since the Workbook provides the details of the intakes for the reactor (in this case ATR-2) that produces the largest dose to the organ of interest, these intakes were adjusted to those for ATR-1 for comparison to the values in Table H-4 (which is an illustration of the intake values for ATR-1). SC&A converted the ATR-2 intake value results from the Workbook to ATR-1 intake values by multiplying the intake values for ATR-2 by the ATR-1 activity fraction from Table 7-3a, then dividing by the ATR-2 activity fraction from Table 7-3b, and then multiplying this result by the ATR-1 Sr-90 activity ratio from Table 7-1a, divided by the ATR-2 Sr-90 activity ratio from Table 7-1a. For example, for Co-60, the conversion from the ATR-2 to ATR-1 intake value would be:

Co-60 (pCi/d) =
5.693E-3 Bq/y × 27 pCi/Bq × (1/365 d/y) × 2.05E-4/2.07E-4 × 0.0214/0.0124 = ***7.20 E-4 pCi/d***

After these adjustments, SC&A compared the intake values in the output of the Workbook to the values in Table H-4 of the OTIB, as illustrated in the Table 3.

Table 3. Comparison of Workbook Results to OTIB-0054 for Example #2

Isotope	Workbook Solu. & Intake (Bq/Yr)	Workbook pCi/day	OTIB-54 Table H-4 pCi/d	(WorkBk)/ (Table H-4)
Ce-141	Max(M)			
	4.09E+03	3.03E+02	3.02E+02	1.00
Ce-144	Max(M)			
	1.37E+03	1.01E+02	1.01E+02	1.00
Co-60	Max(S)			
	9.73E-03	7.20E-04	7.19E-04	1.00
Cs-134	F			
	3.55E+01	2.63E+00	2.62E+00	1.00
Cs-137	F			
	4.79E+01	3.55E+00	3.54E+00	1.00
Eu-154	M			
	1.12E+00	8.28E-02	8.28E-02	1.00
I-131	F			
	5.74E+04	4.25E+03	4.25E+03	1.00
Nb-95	Max(M)			

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Table 3. Comparison of Workbook Results to OTIB-0054 for Example #2

Isotope	Workbook Solu. & Intake (Bq/Yr)	Workbook pCi/day	OTIB-54 Table H-4 pCi/d	(WorkBk)/ (Table H-4)
	3.55E+03	2.63E+02	2.63E+02	1.00
Pm-147	Max(M)			
	1.33E+02	9.86E+00	9.86E+00	1.00
Pr-143	Max(M)			
	3.61E+03	2.67E+02	2.67E+02	1.00
Ru-103	Max(F)			
	2.14E+03	1.58E+02	1.58E+02	1.00
Ru-106	Max(F)			
	8.26E+01	6.11E+00	6.10E+00	1.00
Sr-89	F			
	3.19E+03	2.36E+02	2.36E+02	1.00
Sr-90	F			
	4.75E+01	3.51E+00	3.51E+00	1.00
Y-90	Max(M)			
	4.74E+01	3.50E+00	3.52E+00	1.00
Y-91	Max(M)			
	3.82E+03	2.82E+02	2.82E+02	1.00
Zr-95	Max(F)			
	4.11E+03	3.04E+02	3.02E+02	1.01
	Total:	**6.19E+03**	**6.19E+03**	**1.00**
Input Parameters:	**ATR-1**	Sr-90 indictor	10 day decay	
		Input = 164.0 pCi/d	Gross beta	
			Minimal sample prep.	

As can be seen from this comparison, the Workbook duplicated the values in the OTIB for Example #2 within rounding errors.

Example #3

This example involved an intake period of [**redacted**] using gross gamma air sample data for a worker in a [**redacted**] area; therefore, according to Table 5-3, page 11, a 180-day decay would be used. The maximum gross air concentration measured during the period [**redacted**] was 1E-10 µCi/ml; this corresponds to 658 pCi/d gross gamma intakes, and will be used to bound the intakes.

SC&A found that the Workbook has a box that lists "*Inhalation*," but the user cannot change this selection; i.e., the user cannot select inhalation or ingestion, as it appears that *Inhalation* is locked in the program. Therefore, as an alternative path forward, SC&A calculated the ingested intake values using OCAS-TIB-009, *Estimation of Ingestion Intakes* (OCAS 2004), i.e.:

$$\textit{Ingested intake (pCi/d)} = \textit{Inhaled intake (pCi/d)} \times 0.2 \times 365\ d \times 1/2400 m^3$$
$$\textit{Ingested intake (pCi/d)} = \textit{Inhaled intake (pCi/d)} \times 0.0304$$

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SC&A compared the derived ingested values to those listed in Table H-5, and found them to match.

Identification of Issue

Entering the appropriate parameters into the Workbook provided the resulting three spreadsheets as previously described. The outputs of these spreadsheets were evaluated and compared to the results obtained by hand calculations using Tables 7-4b, 7-3b, and 7-3a as provided in the OTIB, and SC&A also compared the output of the Workbook to the intake values listed in Table H-5 of the OTIB. SC&A found that the Workbook listed the intake and dose values for each radionuclide of interest. However, these output values were much larger than what SC&A calculated by hand or are listed in Table H-5 of the OTIB.

Issue #1 – Lack of Adjustment of Gross Air Input

After identifying this issue, SC&A analyzed Example #3 in detail using the ATR group of reactors as the input to the Workbook (the same results as the OTIB were obtained using all nine reactors, but with numerous combinations and tables to consider, this assisted in identifying the cause of the problem). It is SC&A's understanding of Example #3 that the Cs-137 intake value would be derived by multiplying the gross gamma air concentration (658 pCi/day) by the activity fraction from Table 7-4b (for ATR-2, this would be 1.24E-2). The Workbook indicates that of the ATR reactors, ATR-2 provided for the largest dose in this case. Therefore, SC&A derived a Cs-137 intake value of 8.16 pCi/d (corresponding to 110.3 Bq/year) by multiplying the 658 pCi/d intake rate times the 1.24E-2 activity ratio value for ATR-2 (180-day decay) from Table 7-4b. However, the output of the Workbook lists a Cs-137 intake value of 8,895 Bq/y (corresponding to 658 pCi/day), which is the same as the gross gamma intake value; i.e., the intake value had not been adjusted for the activity ratio from Table 7-4b, and resulted in an intake value of 1/0.0124 = 80.6 times the correct value.

All the other radionuclide intake values provided by the Workbook were correctly obtained by using the ratio values from Table 7-3b for ATR-2, but their absolute values were also 80.6 times the correct values. To compare the Workbook results for ATR-2 to ATR-1 as listed in Table H-5 for Example #3 of the OTIB, SC&A converted the ATR-2 intake value results from the Workbook to ATR-1 intake values by multiplying the intake values for ATR-2 by the ATR-1 activity fraction from Table 7-3a, then dividing by the ATR-2 activity fraction from Table 7-3b, and then multiplying this result by the ATR-1 Cs-137 activity ratio from Table 7-4b, divided by the ATR-2 Cs-137 activity ratio from Table 7-4b. For example, for Co-60, the conversion from ATR-2 to ATR-1 intake value would be:

Co-60 (pCi/d) =
1.735 Bq/y × 27 pCi/Bq × (1/365 d/y) × 1.93E-4/1.95E-4 × 0.0183/0.0124 = ***0.187 pCi/d***

This is 80 times greater than the correct hand-calculated Co-60 intake value for ATR-1 (and also the Co-60 intake value listed in Table H-5 of the OTIB), which is:

Co-60 (pCi/d) = 658 pCi/d × 0.0183 × 1.93E-4 = ***2.32E-3 pCi/d***

A summary of this comparison of all the radionuclides of interest is listed in Table 4.

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Table 4. Comparison of Workbook Results to OTIB-0054 for Example #3

Isotope	Workbook ATR-2 Intake (Bq/Yr)	Workbook *ATR 2 -> ATR 1 pCi/day	OTIB-54 Table H-5 pCi/d	(WorkBk)/ (Table H-5)
Ce-141	Max(M)			
	4.2430E+04	2.23E+03	2.77E+01	80.63
Ce-144	Max(M)			
	1.89E+05	1.85E+04	2.30E+02	80.64
Co-60	Max(S)			
	1.73E+00	1.87E-01	2.32E-03	80.78
Cs-134	F			
	4.12E+03	6.21E+02	7.70E+00	80.71
Cs-137	F			
	8.8952E+03	9.71E+02	1.20E+01	80.92
Eu-154	M			
	1.73E+02	2.20E+01	2.73E-01	80.75
I-131	F			
	1.63E+01	5.08E-01	6.29E-03	80.74
Nb-95	Max(M)			
	3.48E+05	2.55E+04	3.16E+02	80.82
Pm-147*	Max(M)			
	0.00E+00	*2.63E+03*	3.26E+01	80.72
Pr-143	Max(M)			
	3.46E+02	1.25E+01	1.55E-01	80.82
Ru-103	Max(F)			
	3.78E+04	2.18E+03	2.70E+01	80.56
Ru-106	Max(F)			
	1.22E+04	1.23E+03	1.53E+01	80.61
Sr-89	F			
	9.87E+04	6.35E+03	7.87E+01	80.70
Sr-90	F			
	8.81E+03	9.60E+02	1.19E+01	80.71
Y-90	Max(M)			
	8.81E+03	9.61E+02	1.19E+01	80.79
Y-91	Max(M)			
	1.55E+05	1.04E+04	1.29E+02	80.55
Zr-95	Max(F)			
	1.90E+05	1.34E+04	1.66E+02	80.73
	Total:	**8.61E+04**	**1.07E+03**	80.71
Input Parameters:	**ATR-2**	Cs-137 indictor	180 day decay	
		Input = 658 pCi/d	Intake from gross gamma air conc.	

**ATR-1 pCi/d = ATR-2 pCi/d × (ATR-1 ratio/ATR-2 ratio) × 0.0183/0.0124*

***Pm-147 derived from Cs-137: 971 pCi/d × 2.71, because ATR-2 Pm-137 = 0.00*

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As can be seen from this comparison, all the intake values derived by the Workbook for Example #3 are approximately 80 times greater than those listed in Table H-5 of the OTIB, apparently because the activity ratio for Cs-137 was not applied.

After this issue was identified, SC&A investigated further to find that the Workbook derives the correct intake values if the *Urine Activity Fraction* function is selected (minimal or major), but does not apply the activity ratio if this function is not selected (this applies to both urine and air input data, when using either Sr-90 or Cs-137 as the indicating radionuclide, for any of the decay times). Of course, the *Urine Activity Fraction* function cannot be used when using gross gamma air sample data; therefore, the intake results when using gross air sample data are always too large.

Issue #2 – Pm-147 Values Not Available for ATR-2 and ATR-3

The current version of the Workbook erroneously provides output values for Pm-147 for ATR-2 and ATR-3 of zero (which corresponds to Tables 7-3b and 7-3c, respectively, of Rev. 01 of the OTIB[2]). However, the latest version of OTIB-0054, Rev. 02, corrects this error for Pm-147 for ATR-2 and ATR-3. Therefore, the current Workbook provides a zero intake and dose values when there should be some positive values. This omission results in a lesser dose being assigned than recommended in the current version of the OTIB. NIOSH is aware of this discrepancy, since it produced Rev. 2 of the OTIB specifically to correct the Pm-147 values in Tables 7-3b and 7-3c.

1.6.4 Conclusions

In the tests that SC&A has performed, OTIB-0054 Workbook 1.2.0 correctly derives the intake values (except for Pm-147 for ATR-2 and ATR-3) when using Sr-90 or Cs-137 as the indicating radionuclide when used in conjunction with the *Urine Activity Fraction* function. However, the workbook appears to skip the step necessary to apply the activity ratio value (i.e., the fraction of the total measured activity that is due to Sr-90 or Cs-137) from Tables 7-4a or 7-4b in all other cases, resulting in the intake values being substantially too large. This program error will produce intake values that are too large in the output of the Workbook when using gross air concentration in all cases, and also when using urine data if the *Urine Activity Fraction* is not selected. Additionally, the current version of the Workbook (Ver. 1.2.0) needs updating to incorporate the Pm-147 values for ATR-2 and ATR-3 listed in Tables 7-3b and 7-3c of Rev. 2 of the OTIB.

1.7 FINDING 36 (10)

In this finding, SC&A expressed concern that one could envision a situation where two workers are assigned a dose using the OTIB methodology, where for one, the protocol is extremely claimant favorable and the worker is compensated, and for the other, the protocol is less claimant favorable and the claim is denied. SC&A stated that the OTIB would benefit from a discussion of this particular concern.

[2] See the Note preceding the Executive Summary of this report.

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In its February 4, 2014, BRS response, NIOSH stated, "that the goal was to develop a process that had little chance of underestimating a worker's dose. It was never intended to be precise. Additional discussion of that point can be added, as requested." SC&A accepts that the basic approach used in the OTIB is claimant favorable, with due consideration of the question raised under Finding 31 (5), but believes that more discussion of the overall claimant-favorability of the strategy employed in the OTIB is warranted. Hence, SC&A recommends that this finding remain *In Progress*.

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2.0 REFERENCES

Croff 1980. Croff, A.G., *ORIGEN2 – A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980. [SRDB Ref. ID: 23569]

DOE 2003. *Source Term Estimates for DOE Spent Nuclear Fuels*, U.S. Department of Energy, DOE/SNF/REP-078, Rev. 0, March 2003.

OCAS 2004. *Estimation of Ingestion Intakes*, Rev. 0, OCAS-TIB-009. Office of Compensation Analysis and Support, Cincinnati, Ohio. April 13, 2004.

ORAUT 2007. *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, ORAUT-OTIB-0054, Rev. 0 PC-1, November 19, 2007.

ORAUT 2013. *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, ORAUT-OTIB-0054, Rev. 1, June 13, 2013.

ORAUT 2014. *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, ORAUT-OTIB-0054, Rev. 2, March 6, 2014.

SC&A 2008. *Review of ORAUT-OTIB-0054, "Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses," Rev. 0, PC-1*, SCA-TR-TASK3-0006, Rev. 0, March 17, 2008.

SC&A 2013. *Review of ORAUT-OTIB-0054, "Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses," Revision 1*, SCA-TR-PR2013-0084, Rev. 0, November 5, 2013.

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APPENDIX A: EXAMPLE OF WORKBOOK OUTPUT SPREADSHEET – *IREP*

Exposure #	Exposure Year	Exposure Rate	Radiation Type	Distribution	Parameter 1	Parameter 2	Parameter 3		Tag
1	1960	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
2	1960	chronic	electrons E>15keV	Constant	0.001	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
3	1961	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
4	1961	chronic	electrons E>15keV	Constant	0.001	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
5	1962	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
6	1962	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
7	1963	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
8	1963	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
9	1964	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
10	1964	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
11	1965	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
12	1965	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
13	1966	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
14	1966	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
15	1967	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
16	1967	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
17	1968	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
18	1968	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
19	1969	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
20	1969	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
21	1970	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
22	1970	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
23	1971	chronic	electrons E>15keV	Lognormal	0.000	3.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
24	1971	chronic	electrons E>15keV	Constant	0.002	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
25	1960	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
26	1961	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
27	1962	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
28	1963	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
29	1964	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
30	1965	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
31	1966	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
32	1967	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
33	1968	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
34	1969	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
35	1970	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)
36	1971	chronic	photons E>250keV	Constant	0.000	0.000	0.000		OTIB54 Intake 1 (ATR 1,1 y)

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APPENDIX B: EXAMPLE OF WORKBOOK OUTPUT SPREADSHEET – *SUMMARY*

OTIB-0054 Tools Summary																
Report Output:	3/10/2014	4:43 PM		**NIOSH ID:**	[redacted]			**File Name:**								
Tool Version:	1.2.0			**Prepared By:**	DRToolsUser			**Database Version:**	01.08.2014 [Remote]							
Intake Parameters:																
Ind. RN	**Decay**	**Reactor**	**Start**	**End**	**Diagnosis**	**Years Employment**	**Latency**	**Intake**	**Unit/Rate**	**Mode**	**Exp Rate**	**I-131**	**Urine Act. Frac.**	**Distribution**	**GSD**	**Organ**
Sr-90	1y	ATR	[redacted]	[redacted]	[redacted]	12	12	76	pCi/Day	Inhalation	Chronic	Yes	Applied - Major	Lognormal	3	SKIN
	Reactor	**Decay**	**Total**													
	ATR 1	1 y	0.018554													
	ATR 2	1 y	0.017445													
	ATR 3	1 y	0.016912													

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APPENDIX C: EXAMPLE OF WORKBOOK OUTPUT SPREADSHEET – *DETAIL 1*
(1 of 17 radionuclides)

Organ Dose for Unit intake																
Ind. RN	**Decay**	**Reactor**	**Start**	**End**	**Diagnosis**	**Years Employment**	**Latency**	**Intake**	**Unit/Rate**	**Mode**	**Exp Rate**	**I-131**	**Urine Act. Frac.**	**Distribution**	**GSD**	**Organ**
Sr-90	1y	ATR	[redacted]	[redacted]	[redacted]	12	12	76	pCi/Day	Inhalation	Chronic	Yes	Applied - Major	Lognormal	3	SKIN
ATR 1	**1 y**	**Dose Total (rem):**	0.018554													
Ce-141	**Max(M)**	**SKIN**	electrons E>15keV					One column for every year Exposed, one row for every year of Latency								
	Intake (Bq/Yr)	**RN Dose (rem)**	**YEAR**	**SUM**				Data in columns C to CE is equal to Data in column CF times the Intake (in Bq) for that year (row 89)								
1	22.029654	2.039E-09	[redacted]	4.492E-08	4.492E-08											
2	21.969464	2.817E-10	[redacted]	5.1E-08	6.206E-09	4.48E-08										
3	21.969464	1.363E-13	[redacted]	5.099E-08	3.003E-12	6.189E-09	4.48E-08									
4	21.969464	5.413E-17	[redacted]	5.099E-08	1.192E-15	2.994E-12	6.189E-09	4.48E-08								
5	22.029654	2.102E-20	[redacted]	5.111E-08	4.631E-19	1.189E-15	2.994E-12	6.189E-09	4.492E-08							
6	21.969464	7.968E-24	[redacted]	5.1E-08	1.755E-22	4.618E-19	1.189E-15	2.994E-12	6.206E-09	4.48E-08						
7	21.969464	3.084E-27	[redacted]	5.099E-08	6.794E-26	1.751E-22	4.618E-19	1.189E-15	3.003E-12	6.189E-09	4.48E-08					
8	21.969464	1.194E-30	[redacted]	5.099E-08	2.63E-29	6.775E-26	1.751E-22	4.618E-19	1.192E-15	2.994E-12	6.189E-09	4.48E-08				
9	22.029654	4.622E-34	[redacted]	5.111E-08	1.018E-32	2.623E-29	6.775E-26	1.751E-22	4.631E-19	1.189E-15	2.994E-12	6.189E-09	4.492E-08			
10	21.969464	1.751E-37	[redacted]	5.1E-08	3.857E-36	1.015E-32	2.623E-29	6.775E-26	1.755E-22	4.618E-19	1.189E-15	2.994E-12	6.206E-09	4.48E-08		
11	21.969464	6.777E-41	[redacted]	5.099E-08	1.493E-39	3.847E-36	1.015E-32	2.623E-29	6.794E-26	1.751E-22	4.618E-19	1.189E-15	3.003E-12	6.189E-09	4.48E-08	
12	21.969464	2.62E-44	[redacted]	5.099E-08	5.772E-43	1.489E-39	3.847E-36	1.015E-32	2.63E-29	6.775E-26	1.751E-22	4.618E-19	1.192E-15	2.994E-12	6.189E-09	4.48E-08

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