Memorandum

To: SRS Work Group and SEC Issues Work Group
From: SC&A, Inc.
Date: April 21, 2022
Subject: SRS Trivalent Bioassay Variability Status and Recommendation

Background

During the 1970s and 1980s, the Savannah River Site (SRS) performed bioassay analysis for trivalent actinides—americium/curium/californium (Am/Cm/Cf)—for routine internal monitoring and radionuclide intake confirmation and evaluation. These bioassay measurements are captured in laboratory logbooks that demonstrate that SRS often split a single urine voiding into multiple discs or aliquots, which were measured separately and averaged to obtain a reported result. The National Institute for Occupational Safety and Health (NIOSH) used the laboratory logbooks and the individual aliquot measurements in the construction of its co-exposure model as documented in ORAUT-OTIB-0081, revision 05, "Internal Coworker Dosimetry Data for the Savannah River Site" (NIOSH, 2020a; "OTIB-0081").[1]

NIOSH's guiding documentation for the formulation and evaluation of co-exposure modeling is in DCAS-IG-006, revision 00, "Criteria for the Evaluation and Use of Co-Exposure Datasets" (NIOSH, 2020b; "IG-006"). One of the four tenets described in IG-006 is the concept of "data adequacy," the general evaluation of which is described as follows:

> The measurement techniques employed must be evaluated to ensure that they are capable of quantitatively measuring the exposure of interest. [NIOSH, 2020b, p. 5]

IG-006 further states:

> The quality of the available data also needs to be considered. This would include a review of the appropriate collection and analysis of blank samples. When paired measurements are available, the precision between measurements should be examined. **If widely different results from the same aliquot are observed, the effect this might have on the usefulness of the data should be considered**. [NIOSH, 2020b, p. 6; emphasis added]

[1] As discussed later in this report, NIOSH is currently in the process of revising OTIB-0081 to include a recoding of all trivalent bioassay data as well as a statistical analysis of variability.

SC&A first expressed concern about the issue of observed variability among multiple aliquots of the trivalent bioassay samples at SRS as far back as February 2014 (SC&A, 2014, pp. 6–31; SRS WG, 2014, pp. 186–198). The issue of data adequacy and variability was discussed in multiple meetings of the Special Exposure Cohort (SEC) Issues work group (WG) (SEC WG, 2014a, pp. 11, 14; 2014b, p. 18; 2015, p. 72) and by the joint SRS and SEC Issues WGs (SRS WG & SEC WG, 2017, p. 110, 113; 2019, p. 12). Additionally, the issue of observed variability of multiple aliquot measurements was discussed in attachment D of OTIB-0081, which documents the overall SRS co-exposure model (NIOSH, 2020a, pp. 159–163), and in SC&A's review of the prior revision of that document (SC&A, 2020a, pp. 15–20).

Most Recent Document Exchanges and Work Group Discussion

The most recent pertinent technical documents were issued in 2020 and involved an SC&A memorandum to describe the current status of the issue and a NIOSH response to SC&A's memorandum:

- SC&A (2020b): "Summary Position on Trivalent Bioassay Variability"
- NIOSH (2020c): "Response to SC&A Memorandum, 'Summary Position on Trivalent Bioassay Variability'"

Each of these document's conclusions are briefly summarized in the next two paragraphs, respectively.

SC&A (2020b) concluded that the observed variability in trivalent actinide bioassay samples had not been sufficiently explained to justify its use in either individual dose reconstruction or co-exposure formulation. This conclusion was based on SC&A's interpretation of the IG-006 co-exposure guidelines concerning data adequacy as summarized in the background section of this memorandum. SC&A found that the observed variability in selected examples fell outside of the precision reported in a 1987 SRS procedure (SRS, 1987, pp. 60–65). More importantly, SC&A determined that pertinent information to correctly interpret and validate the SRS trivalent bioassay data was lacking. Such information includes laboratory benchtop procedures, documented quality assurance tests, prospective acceptance criteria for blanks/spikes, and formal laboratory calculations with clear indications of necessary terms (volume, counting efficiency, chemical yield, measurement uncertainty). SC&A also indicated that, while formal documentation may be lacking, interviews with subject-matter experts may also provide useful information to understand and interpret the available trivalent actinide data. Finally, SC&A did not accept NIOSH's contention that the averaging mechanisms of the co-exposure process obviate the observed variability and data adequacy concerns.

NIOSH's (2020c) response noted that the examples provided by SC&A were selective and that the determinations of acceptable variability were ultimately subjective. NIOSH reasoned that there are realistic situations in which a given sample might display subjectively high variability without calling into question the analysis method. In particular, NIOSH offered an example involving a suspected uptake of radioactive material in which the efficiency, rather than the precision, of the analysis is of more import to quickly identify and treat the individual (e.g., through administration of chelating agents). NIOSH also asserted that there is no real criterion for acceptable variability among sample aliquots even by contemporary radiochemical laboratory

standards. NIOSH proposed that a more rigorous statistical metric of variation, such as the coefficient of variation (COV), is more appropriate in evaluating the variation among aliquots. Regarding the availability of documentation about specific processing activities of the SRS bioassay laboratory, NIOSH noted that such documentation is certainly desirable but generally unavailable for capture and interpretation, particularly before the advent of the U.S. Department of Energy Laboratory Accreditation Program (DOELAP). NIOSH commented that the bioassay logbooks themselves had evidence of blanks/spikes being used. In addition to the blanks/spikes, it was apparent that SRS personnel had reviewed and signed off on these logbooks, which provides weight of evidence as to the data's veracity. NIOSH concluded that absent contradicting information (e.g., evidence of falsification, records destruction, typographical database errors), the "fitness of the analytical results for the original intended purpose implies fitness for use in dose reconstructions in a compensation program" (NIOSH, 2020c, p. 8).

These two previous technical documents were presented and discussed at the joint meeting of the SRS and SEC Issues WGs on November 20, 2020. As a result of those discussions, the WGs tasked SC&A and NIOSH with the following two actions (SRS WG & SEC WG, 2020, pp. 132–135):

1. SC&A is to develop a set of specific technical questions and provide those questions to NIOSH in preparation for a technical call to be held between NIOSH, SC&A, and WG members (as available).

2. NIOSH is to complete its recoding effort for the trivalent actinide bioassay data, which includes a detailed review by a health physicist prior to completion. NIOSH will then provide updated co-exposure estimates along with an analysis of the COV as recommended in NIOSH (2020c). SC&A is to review the COV analysis when available.

The next section describes the progress made on action item 1. As of this writing, action item 2 is still in progress with NIOSH, who are revising OTIB-0081 to include the recoded trivalent actinide data and an analysis of the COV for the entire dataset (the upcoming revision will be revision 06 of OTIB-0081).

Progress and Status of Action Item 1

SC&A delivered a set of technical questions to NIOSH on January 5, 2021, and held a technical call on January 28, 2021, to address the submitted questions. The list of SC&A's original questions and SC&A's meeting minutes of the technical call[2] are included for reference in attachments A and B, respectively. After that technical call, NIOSH provided SC&A with some example SRDB reference numbers that may contain the type of information sought to resolve concerns over data adequacy. NIOSH also indicated that there may be other such examples in the SRDB. Unfortunately, SC&A is still unable to access the SRDB due to access restrictions imposed by the cybersecurity modernization initiative. However, the original SRDB references indicated by NIOSH in February 2021 were made available to SC&A in January 2022 via the

[2] SC&A submitted meeting minutes to NIOSH on January 29, 2021, for comment and modification (as needed), which resulted in a followup email from NIOSH that gave additional information and Site Research Database (SRDB) references that were germane to the additional information sought by SC&A.

new secure access module called the NIOSH Edge Computing Platform. The following list briefly summarizes the supplied SRDB file contents and relevance:

- Dupont Savannah River Operating List (DPSOL) 47-206, revision 1, "Americium-Curium-Californium, Plutonium, Neptunium, Enriched Uranium Sequential Determinations" (SRS, 1987): This DPSOL was also reviewed for SC&A's (2020b) memorandum to the WG. This document provides generic information, such as the minimum detectable activity (MDA) and the estimated precision at the 95th percentile confidence level.

- Dupont Standard Operating Procedure (DPSOP) 47, revision 28, "Radiobioassay Laboratory Procedures" (SRS, 1991): Contains updated generic procedures with various dates between 1986 and 1991. This DPSOP also contains duplicate versions of the previous record (as DPSOP 47-206, rev. 1). Documentation indicates that the transuranic bioassay analysis procedure had been integrated into Health Physics (HP) Manual 5Q2.3.

- OSR 4-257, "Sample Counting Data Sheet" (SRS, 1977): This SRDB file contains hundreds of examples of filled-out sample counting data sheets (Form OSR 4-257), which collect bioassay-specific information such as counting times, sample number, logbook reference, total counts, background counts, disintegrations per minute (dpm) per disc, conversion factors, dpm per liter, and a remarks column. While many of the example counting sheets do not specify a year, it is likely that they are from 1977, based on other dated documents in the file.

- OSR 4-298, "Health Physics Bioassay Tritium Data (Receiving Report) (Computer Document)" (SRS, 1980): This SRDB file contains hundreds of tritium bioassay logsheets from 1980. The logsheets have fields for the following entries: roll code, roll prefix, employee number, date (month and day), result (microcuries per liter), area, department, employee name, sample counts, and a checkbox to indicate whether the sample was routine or special.

While informative, SC&A does not find that these standard procedures and example counting sheets necessarily provide the sought-after details on actual laboratory procedures at the benchtop level.

Additionally, NIOSH indicated that other examples may exist at SRS itself that have not been captured and provided some potential "box" descriptions of hardcopy records that include information such as:

- Counting room daily reports
- Counting room source checks
- Alpha spectrometry raw data
- Tritium quality control (QC) data
- Gamma spectrometry
- Plutonium alpha spectrometry data
- Enriched uranium alpha spectrometry data

However, SC&A notes that many of the resources in this list refer to the spectrometric analysis method, which was not used at SRS during the period of interest (before 1990), and that routine samples were not analyzed via spectrometry until 1995 (NIOSH, 2019, p. 41).

Status and Path Forward

Based on the technical call and additional SRDB documents supplied by NIOSH, it is apparent to SC&A that while examples exist of the types of laboratory quality assurance (QA) and process specific information (inclusion of blanks and efficiency documentation) requested, actual benchtop procedures of the type of specificity that SC&A was seeking have not yet been located. Additionally, it is somewhat questionable whether that type of information would still be available. As noted by NIOSH (2020c, p. 6):

> Locating and vetting radiobioassay analytical results for a facility is in itself a difficult task. Locating all relevant procedures and QA records for those results is usually not feasible, especially in the pre-DOELAP era (i.e., before 1996).

SC&A (2020b) had also indicated that a second potential source of information would be to seek out interview subjects who may have first-hand knowledge of the laboratory operations during the pre-1990 time period. While it is always helpful to speak to former workers with specific experience, NIOSH (2020c) noted another potential pitfall in its response:

> Considerable subject matter knowledge would be required to properly interpret procedures and QA records (especially for pre-DOELAP analyses) in any effort to verify what the cognizant technical authority (e.g., the radiochemist) approved at the time of the analysis (as indicated by his/her signature). [NIOSH, 2020c, p. 6]

Nonetheless, SC&A was able to examine the claimant population for potential interview subjects before the cybersecurity modernization initiative and located 11 individuals who indicated some experience working in the bioassay laboratory. Attachment C briefly summarizes these 11 individuals. However, SC&A notes that few of these individuals appear to qualify as the type of high-level radiochemist who would bring the necessary expertise to answer some of SC&A's very specific laboratory process questions.

Finally, SC&A notes that NIOSH is in the process of recoding all of the trivalent americium data from the hardcopy logbook data with a focused review of each datapoint by knowledgeable NIOSH health physicists. As part of that effort, NIOSH has committed to performing a rigorous statistical evaluation of the COV, which will likely significantly inform future discussions. As this new material has not yet been finalized, SC&A is not in a position to comment on its conclusions. However, SC&A believes this statistical avenue to likely be the most fruitful in resolving the ongoing data adequacy concerns about the trivalent bioassay data.

References

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Attachment A: SC&A's Clarifying Technical Questions Transmitted to NIOSH on January 5, 2021

In general, SC&A is less concerned about what was done for each individual measurement (i.e., validating each datapoint) and more concerned with the overall process. To try to illustrate this, please consider the following simplified example:

SRS identified that urine samples would be processed in accordance with "Procedure X," counted on "Counter Y," and calculated in accordance with "Procedure Z," and that X, Y, and Z contained the pertinent technical details:

- Did Procedure X state the use of reagents at specific concentrations and volumes, including tracers, spiked and blanks samples, without regard for using 6N HNO3 versus 8N, or 1 spike per day versus 1 spike per batch of 20?

- Did the procedure for Counter Y require a determination of measurement efficiency (cpm/dpm) and was it required to check this, without regard for what the efficiency value was or how often it was checked?

- Did Procedure Z specify how to derive the final values, including the assigned chemical recovery for each batch/sample/whatever, dilution factors without regard for what the values were?

Specific Questions:

- Is there a record of what analytical procedures were used for chemical separation, radiometric assay (counting) and calculation over specific time periods? Examples:
  - SRS laboratory procedures for chemical separations;
  - Identification of the counters used;
  - Method for converting counting data into concentrations of target analyte per unit volume of urine for reporting (dpm/1.5L)
- Has the method of determining the efficiency of the analytical process (chemical separation, mounting, counting, etc.) been established? Examples:
  - How did the laboratory personnel know how much of the target analyte was identified in a sample such that the results could be correlated to the actual target analyte concentration in the sample?
  - How did they account for losses during processing?
  - How was the detection efficiency (cpm/dpm) of the radiometric equipment determined?
- Are there records that indicate the process that SRS executed from start to finish? Examples:
  - Sample tracking;
  - Determination of appropriate volumes for specific purposes;

  - Data review;
  - Evaluation of sample results relative to predetermined acceptance criteria;

- Are there SRS laboratory personnel who processed these bioassay samples, and are we able to access them for some simple questions?

Attachment B: SC&A's Meeting Minutes from the Technical Call held January 28, 2021

NIOSH: The degree to which we can answer these questions is highly dependent on time period. In the late 1970s and 80s–90s, we have record of the specific laboratory analytical procedures. In the earlier time periods we don't have the site-specific procedures. In the 1960s, we have largely the description of what they were doing at conference proceedings. You can infer that some of these things were being done.

SC&A: I was not able to clearly correlate a procedure from SRS or otherwise with a time period.

NIOSH: There are specific SRDBs (DPSOLs), one of which is 1991.

NIOSH: SRDB 86192 contains some of the DPSOL 47 procedures. It talks about the sample counting data sheets. They entered the counter, how the logbooks were compiled.

SC&A: Does that identify the actual type of counter?

NIOSH: This particular procedure is used for Am/Cm/Cf, Pu etc. on how to fill out the sample data sheet. A lot of the early procedures used were published into peer reviewed journals. Then they got migrated into DPSOLs. Keep in mind, I mentioned the sample counting datasheets, we have examples in the SRDB. And there are examples of that datasheet going back to the 1960s.

SC&A: The analytical procedures to determine the aliquot size, separation chemistry, chemical yield, mounting, counting, data reduction, etc., these are in the DPSOL procedures?

NIOSH: When we get into the 1990s it's not DPSOLs but it's 5Q or something.

NIOSH: Some of what we have are DuPont procedures that carried out into the Westinghouse era.

NIOSH: Going back from earlier than 1986 or so we don't necessarily have the procedures, but they were documented in the peer reviewed journals.

SC&A: So, we don't have necessarily a benchtop procedure.

NIOSH: I'm not sure if we have the rev. 01 version of these procedures. Also searching in EDWS—that's where a lot of this information came from—I'm not sure we've gone into the level of detail that SC&A is looking for. I know that some of the datasheets that have efficiencies and such we have not captured. That does not mean that it doesn't exist. I know there are boxes of sample counting sheets that are still on site.

SC&A: On the second bullet . . . any sort of benchtop procedure will have losses due to chemical processing, so we're trying to figure out how those were dealt with. I don't have any doubt that the samples were processed with some basic sample chemistry (basic solubilities, aqueous versus organic fractions, etc.). How did they determine what the processing losses were and correct for them? Typically this is done with (chemical yield) tracers of stable carriers (not applicable for Am). How do you determine the measurement efficiency (cpm/dpm) of the counters? These are

the basic aspects of a radiochemical assay, really the two most important things with respect to the data reflecting reality. The key question is: Was there an acknowledgement of the importance of these aspects and is that captured in documents that were formalized, served as the basis for personnel training, and were maintained under some types of revision control? Essentially, was there a formal system of controls for all aspects of the analytical process? I'm less concerned about the details of the processing of each specific sample.

NIOSH: What would you need to satisfy your question? We have the OTIB references, which describe an MDA. We have the logbooks that show they were regularly counting the blanks and spikes, subtract background, and efficiencies. There was evidence they were doing that.

SC&A: There is certainly evidence those types of activities were occurring in general. But more specifically, was there a predetermined acceptance range for blanks and spiked samples? How were the measurement efficiencies established? What type of radiometric instruments were used? It was clearly not alpha spectrometry for the earlier assays. I agree there is inferential information out there—you can see that in the logbooks I looked at—there were typically a blank and spiked sample analyzed with most batches.

NIOSH: I don't think I've seen a procedure that outlines everything that you're talking about there. But in the EDWS there are boxes of data such as for QC data for tritium. Counting room source checks/Pu alpha spectrometry data . . . we have not yet captured any of that information. Some of it is likely still in hard copy. So it sounds like some of what you are looking for is that level of detail, but I'm not sure we have that. You may find examples of it, but not to the level you're looking for.

SC&A: If those kinds of things exist for the Am data, then that would certainly be helpful.

NIOSH: What we do is when we need information, we go to the site and scan it and upload it to the SRDB. SRDB 53258 has plutonium information in it which may be helpful.

Attachment C: Potential Interview Subjects Identified in the Claimant Population

Case ID *	Approximate relevant employment period	Position title	Summary of relevant experience identified in the computer-aided telephone interview and/or Department of Labor case files
A	Mid to late 1980s	Laboratory Technician	[redacted]
B	1980s	Laboratory Technician	[redacted]
C	1970s and 1980s	Laboratory Technician	[redacted]
D	1970s and 1980s	Chemist, Manager	[redacted]
E	1970s and 1980s	Supervisor, Laboratory Technician	[redacted]
F	1970s and 1980s	Technical Assistant, Health Physics	[redacted]
G	Late 1970s and early 1980s	Laboratory Technician	[redacted]
H	1980s	Clerk, Laboratory Technician	[redacted]
I	Mid 1980s	Laborer, Laboratory Technician	[redacted]
J	1980s	Laboratory Technician, Technical Analyst	[redacted]
K	1970s and 1980s	[redacted]	[redacted]

* The “Case ID” is an arbitrary number assigned by SC&A to protect claimant privacy.