Memorandum

To: Savannah River Site and SEC Issues Work Groups
From: SC&A, Inc.
Date: January 23, 2020
Subject: Response to ORAUT-RPRT-0091, "Evaluation of Savannah River Site Americium-241 Source Terms Between 1971 and 1999 Using Bioassay Frequency Tables"

At the November 14, 2017, Savannah River Site (SRS) Work Group meeting, SC&A noted in its presentation a concern that some SRS workers may have been enrolled in incorrect routine bioassay programs prior to 1999 (SRS Work Group, 2017, pp. 78–79). SC&A noted that unrecognized americium-241 (Am-241) sources were not included in Radiological Work Permit (RWP) preparation and that some workers were unmonitored for americium. We also noted that a sitewide formal radiological hazard characterization process was established by Westinghouse Savannah River Company (WSRC) on March 10, 1999.

SC&A provided the work group and National Institute for Occupational Safety and Health (NIOSH) the three primary Site Research Database (SRDB) references for this finding: SRDB Ref. IDs 167760 (Findley, 1997), 167754 (Farrell & Findley, 1999), and 167753 (WSRC, 1998). The work group subsequently asked that SC&A detail its concern "such that the workgroup and NIOSH can review for potential impact on monitoring methods" (Taulbee, 2017, p. 2). SC&A provided its review in a January 11, 2018, memorandum (SC&A, 2018) that listed these and other relevant SRDB document references and what implications and questions they may hold for the question of whether Am-241 was properly reflected in the SRS bioassay program, given WSRC's self-assessment finding in 1999 (Morgan, 1999). A broader concern is whether the enrollment of workers in SRS bioassay programs may have been historically affected by what was apparently incomplete characterization of facility radiological source terms.

In its conclusion and recommendation to the work group, SC&A stated the following:

> SC&A believes that . . . there was a clear deficiency recognized that may have impacted the proper bioassay enrollment of workers under RWPs prior to the implementation of a new site-wide formal policy, "Specifications of Urine Bioassay Requirements on Radiological Work Permits," issued on March 10, 1999. Lack of proper specification of radionuclides of significance for internal dosimetry may have led to unmonitored exposures for which dose reconstruction with sufficient accuracy may not be feasible. This concern should be investigated further to ascertain its significance, scope, and implications for dose reconstruction. [SC&A, 2018, p. 6]

NIOSH reviewed SC&A's memorandum report and provided its response on June 10, 2019, in ORAUT-RPRT-0091, "Evaluation of Savannah River Site Americium-241 Source Terms Between 1971 and 1999 Using Bioassay Frequency Tables" (NIOSH, 2019a; "RPRT-0091").

Origin of concern

In its RPRT-0091 response (section 2), NIOSH appears to agree with SC&A that the WSRC self-assessment (performed in response to a 1999 U.S. Department of Energy (DOE) Office of Enforcement and Investigation review of 31 general deficiencies found in dose evaluation programs) found that "in some areas site workers were potentially exposed to americium, but that radionuclide was not recognized as an issue when preparing RWPs for those areas" (Morgan, 1999, p. 6). NIOSH further noted that WSRC responded to this finding by listing improvements that had been made in the documentation and review of the radiological hazards, including "Specification of Urine Bioassay Requirements on Radiological Work Permits" (Farrell & Findley, 1999), which defined a more formal, systematic method of determining radiological source terms for bioassay compliance.

As summarized by NIOSH, the root of this issue appeared to be reliance by operations managers responsible for establishing bioassay frequency requirements for RWPs on longstanding bioassay frequency tables rather than identifying actual radionuclides of concern at the job site:

> Before March 1999, site bioassay control procedures included a table of locations and job functions with recommended routine bioassay sampling types and frequencies. The radioisotope selection for each location was primarily based on process knowledge. The 1998 FEB audit found that some individuals responsible for establishing the bioassay requirements in RWPs were relying solely on the tables instead of establishing the radioisotopes actually present as required by the procedures . . . . [NIOSH, 2019a, p. 8]

Beginning in March 1999, the bioassay frequency tables were dropped from WSRC procedures, and all radionuclides potentially contributing 10 percent or more of the inhaled dose from the material present were to be monitored (LaBone, 2004).

Description of SRS internal dosimetry program

In section 3 of RPRT-0091, NIOSH describes the SRS in vivo and in vitro bioassay monitoring programs. SC&A's only comment regarding this description is that the policies of the WSRC era (post-1989) are not clearly distinguished from those of the DuPont era that preceded it. For example, it is noted that "from 1971 through 1999, SRS performed in vivo and in vitro sampling for radioactive material using both routine and special sampling" (NIOSH, 2019a, p. 8). However, immediately following that statement, NIOSH cites three ranges of internal exposure probability that hinge on a 100 millirem (mrem) annual dose to determine whether routine bioassay monitoring under Title 10 of the Code of Federal Regulations (10 CFR) paragraph 835.402(c) would be required. However, it needs to be emphasized that DOE's 10 CFR part 835 regulations were not promulgated until 1995, and similar requirements for routine bioassay monitoring at a 100 mrem per year threshold were first issued in DOE Order 5480.11 in late 1988, with implementation required a year later (DOE, 1988). While such monitoring

requirements were clearly incumbent upon SRS during the WSRC era, they were not during the period of the DuPont operating contract (prior to April 1, 1989).[1]

Likewise, the radiation protection operating philosophy of "Defense in Depth" that is cited in RPRT-0091 was conceived and implemented by WSRC in the 1990s. No such operating philosophy is evident in DuPont policies and procedures of the 1970s and 1980s.

SC&A agrees with NIOSH's summary of the SRS routine bioassay program (including special bioassays) but again observes that the description and citation provided for "job-specific bioassays" is based on WSRC procedures, not those of DuPont. As emphasized in SC&A's response (SC&A, 2019) to NIOSH's recent ORAUT-RPRT-0092, "Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site" (NIOSH, 2019b; "RPRT-0092"), job-specific bioassays as required by RWPs were not codified in SRS procedures until 1990–1991 by WSRC. As acknowledged by NIOSH in RPRT-0092, DuPont relied upon its DuPont Savannah River Operating List (DPSOL) procedures to judge when job plans were needed. It is not clear from these procedures if and when job-specific bioassays would have been required as part of these job plans.

NIOSH's review of the SRS special bioassay program in RPRT-0091 notes that, in an interview with a former employee who worked in the [redacted] program in 1986–1995, the interviewee indicated that there never was a question regarding source term characterization for special bioassay samples because there was "required specification of the source term by analysis of the contamination that triggered collection of the sample" (NIOSH, 2019a, p. 10).

First, this interviewee comment applies to the "special bioassay" program, not the regularly scheduled or job-specific bioassay programs. Second, while DuPont defined and implemented its bioassay program consistent with DOE Order 5480.1, Chapter XI (DOE, 1981), that early version of DOE orders provided wide latitude to DOE operating contractors to define and tailor their own radiation protection procedures and practices. For bioassay programs, DuPont DPSOL procedures were more "general" in nature (as pointed out by NIOSH in RPRT-0092), with facility-based health protection operations managers responsible for maintaining and updating bioassay sampling type and frequency tables. As pointed out in SC&A's review of RPRT-0092, whether facility radionuclides of concern, as characterized for bioassay purposes, were accurate and updated for changes in operation or experience is questionable during the DuPont era. Toward the end of that era, SRS source terms became more diverse and dynamic due to emerging and expanding operations, including decontamination and decommissioning (D&D), environmental cleanup, and waste management. General DPSOL job plan and bioassay requirements, coupled with delegated interpretation and implementation of those requirements through facility managers,[2] would have made consistent radiological characterization difficult.

[1] Given the 1-year implementation period for DOE Order 5480.11, the 100 mrem threshold for monitoring would have been required of contractors by the end of December 1989.

[2] Facility manager judgments had been based on "process knowledge . . . procedural guidance and professional judgement" (Farrell & Findley, 1999, p. 1), but not the updated use of process and waste stream analysis data as in later years.

As pointed out by SC&A in its November 12, 2019, review of RPRT-0092 (SC&A, 2019, p. 25), the DOE Tiger Team assessment in 1990 found that:

> The [WSRC] internal dosimetry program does not comply with the requirements of DOE 5480.11. Radiological areas have not been sufficiently characterized to provide a technical basis for the assignment of bioassay sample types and frequencies. [DOE, 1990, p. 4-193]

This finding was based on a sitewide assessment of the internal dosimetry program that found, in 1990, only one facility at SRS—the Naval Fuel Facility—had been properly characterized in conformance with DOE Order 5480.11 for radiation protection. In its June 20, 1990, action plan response, WSRC (1990a) agreed that a "formal technical basis for the SRS bioassay program has not yet been established" (PDF p. 432). While WSRC emphasized that its bioassay tables were based on "experience" and "common sense," it nonetheless agreed that "during the development of the technical basis manual this year [1990], the radionuclide materials at each area on the site are being characterized" (WSRC, 1990a, PDF p. 432).

It should be noted that the Tiger Team assessment of 1990 was one of three external, independent assessments of late-1980s DuPont era implementation of nuclear and radiological safety programs.[3] The other two were the National Research Council's (1987) review of "Safety Issues at the Defense Production Reactors: A Report to the U.S. Department of Energy," and the congressional investigations and hearings surrounding the aborted P-Reactor restart in 1988 (Nuclear Reactor Safety, 1988; P-Reactor Operations, 1988). All three independent reviews identified concerns with how DOE and DuPont defined, implemented, and oversaw critical safety programs at SRS. For example, the joint House and Senate congressional hearings investigating the circumstances surrounding reactor operator mishandling of anomalous energy spikes in the restart of P-Reactor at SRS in August 1988 surfaced evidence that DuPont technical specifications, procedures, and practices (1) were out of step with accepted practice in the commercial nuclear sector and (2) were not being implemented consistently and with accountability.

That DuPont had state-of-the-art monitoring capabilities, defined bioassay type and frequency tables, developed successive procedures for bioassay program implementation, and manifested a large number of in vivo and in vitro bioassays, as noted in RPRT-0091 (section 3), belies the issues, in question, of whether radionuclides of concern were adequately characterized and whether facility operations managers kept pace with more dynamic source terms as SRS operations evolved in the mid to late 1980s to include D&D, waste management, environmental cleanup, and other new missions and facility campaigns. These would have introduced different process and waste streams into operations such as facility 773-A and Solid Waste Management. Whether these were adequately reflected in Special Work Permits (SWPs) and job plans and whether corresponding radionuclides of concern were required as part of job-specific bioassays have not been established in either RPRT-0091 or RPRT-0092. However, it is clear that, after broader nuclear and radiological safety concerns were raised by external expert groups and DOE

[3] While the Tiger Team review took place about a year after WSRC assumed the SRS operating contract, WSRC had yet to implement its Radiological Improvement Plan and revise sitewide radiation protection procedures, which commenced in late 1990.

headquarters, WSRC moved forward to revamp SRS safety philosophy and culture[4] and, as a component of its Radiological Improvement Plan, reconfirm its sitewide facility source term characterizations and upgrade its characterization process to ensure a more objective, systematic review. In March 1999, WSRC dropped bioassay frequency tables from its procedures because of overreliance by facility managers in using then to prepare RWPs as opposed to actual identification of job-related radionuclides of concern.

To what extent this new analytical process led to different conclusions than the older, more experience-based process is open to debate. While a comparative analysis could be conducted facility by facility, such a review would still not answer the essential question of whether more dynamic (short-term, campaign-driven) sources were adequately reflected in DuPont era job plans and accompanying job-specific bioassays.

Americium, curium, and californium source terms

SC&A does not dispute NIOSH's review and analysis in section 4 of RPRT-0091 as it pertains to the locations identified for americium/curium/californium (Am/Cm/Cf) routine monitoring and the 10 new locations in addition to 773-A identified later by Farrell and Findley (1999). Likewise, SC&A agrees with NIOSH's section 5 summary of the scope of bioassay and air sample monitoring implemented at SRS as it pertains to the WSRC operations in the 1990s. It is clear from this review that one facility, the Multi-Purpose Processing Facility (MPPF), was not listed in the bioassay frequency tables before 1999, and another facility, building 221-F (in which the MPPF was located), had no requirement for Am/Cm/Cf bioassay monitoring.

From NIOSH's section 5 (dose reconstruction) review, it is clear that while urinalyses for Am/Cm/Cf were discontinued in 221-F in 1989, chest counting continued in the 1990s, and any positive results for plutonium (which was required for selected facility personnel) would have distinguished and quantified any Am-241 present. RPRT-0091 also notes that "routine urine bioassay sampling for americium was required on job-specific RWPs during that time" (NIOSH, 2019a, p. 27). However, as noted earlier, SC&A emphasizes that while this may have been the case during the WSRC era, it was not during the DuPont operating era, when an RWP process was not implemented (RWPs were required in procedures but not carried out) and procedures for bioassay monitoring were general in nature.[5]

From an operational standpoint, NIOSH points out that the MPPF was inactive for much of the 1990s, with a demonstration project involving an americium/curium solution not being processed until 2004–2005. What radiological activities did occur are reflected in RWPs in 1996 and 1998 (as listed in tables 5-3 and 5-4) that illustrate work procedures and bioassay required for plutonium, strontium, and americium, accompanied by corresponding records documenting specific worker RWP sign-in/sign-out dates for both in vitro and in vivo bioassays.

[4] The issue and status of safety culture changes undertaken at SRS are addressed by the General Accounting Office (GAO) in its 1991 report (GAO, 1991).

[5] The March 1990 DOE headquarters Tiger Team assessment for SRS found (finding RP. 1-2) that "Radiation Work Permits or Standing Radiation Work Permits are not used even though required by Westinghouse Savannah River Company procedures and accepted industry practice" (DOE, 1990, p. 4-307). DOE further found that "the use of RWPs has been discontinued for years; however, neither the procedures nor SHB-1 [Special Hazards Bulletin in DPSOP-40, rev. 82, September 1989] has been changed" (DOE, 1990, p. 4-307).

Overall, SC&A agrees that for the two facilities for which Am-241 as a source term was not identified in SRS procedures or bioassay frequency tables before 1999 (MPPF and building 221-F), there are mitigating circumstances that make that lapse not a specific concern for dose reconstruction.

Response to NIOSH's RPRT-0091 responses to SC&A questions

The rest of this memo addresses section 6.1 of RPRT-0091, in which NIOSH responded to questions raised in SC&A's (2018) memorandum.

RPRT-0091 section 6.1: Inadequacies vs. continuous improvement

NIOSH prefaced its response to questions posed in SC&A's (2018) memorandum with the following statement:

> SC&A asked questions about the conditions at SRS before 1999 and described the facility source terms at SRS before 1999 as "inadequate". The term "inadequate" is their professional judgment. A different interpretation is that the changes in the routine bioassay program after the characterization effort were continuous improvements in worker monitoring. [NIOSH, 2019a, p. 31]

In its January 11, 2018, memorandum report, SC&A described its concern based on a 1999 WSRC self-assessment finding regarding Am-241 that resulted in a notable change in WSRC bioassay procedures for identification of radionuclides of concern for RWPs. From this self-assessment and other program documentation, SC&A found that "there was a clear deficiency recognized that may have impacted the proper enrollment of workers under RWPs prior to implementation of a new site-wide formal policy . . . issued on March 10, 1999" (SC&A, 2018, p. 6). SC&A never prejudged whether the facility source terms at SRS before 1999 were "inadequate." NIOSH appears to be referring to SC&A's summary of SRDB Ref. ID 167753 (WSRC, 1998), wherein SC&A noted that "the implication of all of the above [contents of WSRC (1998)] is to raise questions and concerns over how facility source term characterizations at SRS had been performed before WSRC realized that they may be inadequate or incomplete" (SC&A, 2018, p. 2).

SC&A's position remains the same whether one interprets the WSRC changes made as done to address program inadequacies or as continuous improvements. That is simply the classic "glass half full" versus "glass half empty" analogy. The real issue is that both DOE headquarters (DOE, 1990) and a WSRC self-assessment (Morgan, 1999) found concerns about how radiological source terms were being characterized at SRS, leading to procedural changes and reverification of sitewide facility "radionuclides of interest" for purposes of RWPs. It is the implications of those concerns for possible missing source terms and incomplete worker enrollments at SRS prior to these program changes that was the basis for SC&A raising its concern to the Advisory Board on Radiation and Worker Health.

RPRT-0091, section 6.1.1: Americium and aging plutonium

NIOSH observes that one change in moving from production to D&D was "a change from working with freshly separated production materials to older waste materials with increased amounts of americium" (NIOSH, 2019a, p. 32). A side benefit of increasing fractions of Am-241

in aging plutonium is that detection is more readily accomplished. SC&A understands this distinction and agrees with NIOSH's statement. NIOSH also pointed out that in instances where pure Am-241 contamination may have been present at MPPF, RWP and job-specific bioassay records show that all affected workers were monitored directly or indirectly for Am-241.

RPRT-0091, section 6.1.2: Followup on cited references

NIOSH summarized each of the SRDB documents listed by SC&A in its January 11, 2018, memorandum. SC&A has no comment.

RPRT-0091, section 6.1.3: Questions raised by SC&A

SC&A included a series of amplifying questions throughout its January 11, 2018, memorandum. NIOSH provided specific responses to each.

SC&A question 1: Ramifications to dose reconstructions

SC&A (2018, p. 2) asked:

> What are the ramifications to dose reconstruction with sufficient accuracy if RWP job-specific bioassays neglected to include relevant radionuclides, particularly for certain facilities where complex, mixed, or unusual radioactive sources existed, e.g., SRTC, solid waste, burial grounds, tank farms, and decontamination and decommissioning projects?

In its response, NIOSH emphasizes, in part:

> There are not any ramifications to dose reconstruction because the relevant radionuclides were included in the bioassay program. There were relatively few changes in the bioassay monitoring by area from 1971 through 1999 with the exception of americium as discussed in Section 4.0 of this report. [NIOSH, 2019a, p. 34]

This assertion is made based on an area-by-area comparison over time. However, it does not address whether the "relevant radionuclides" so identified were, in fact, complete based on a comprehensive and dynamic analysis of what radiological sources were being handled, campaign-by-campaign and job-by-job, at SRS. The importance of this consideration was emphasized by WSRC:

> Additionally, **certain facilities such as the Savannah River Technology Center (SRTC) and the solid waste disposal facilities handle a wide array of radioactive materials, some of which may not be encountered in the typical radiological work environment by workers in those areas**. For facilities such as 221-FB-Line, where the source term is well defined and not subject to change, this is not a concern unless there is a major change in the facility mission. To ensure that the proper radionuclide(s) is identified for the RWP urine sampling program it may be necessary to perform a thorough characterization of the work environment. It is important also that this characterization be performed on a

> routine basis to stay current on the source term present. [Emphasis added.] [WSRC, 1998, p. 2]

In their reassessment of SRS source characterization, WSRC recognized the diversity of sources that facilities such as 773-A handled, particularly with the expanding waste management mission, and the need to ensure that for RWPs and job-specific bioassays the identification of "radionuclides of interest" was done accurately. As a followup to an SRS Facility Evaluation Board (FEB) review, WSRC identified the underlying concern as one of "how the Radiological Control organizations determine which radionuclide(s) of concern are identified on the RWP and how these determinations are made" (WSRC. 1998, pp. 2–3). Such constantly updated, routine characterization of not just areas or facilities, but also operations and jobs within those locations, had not been accomplished during the DuPont era and was still not sufficiently comprehensive as of the 1999 WSRC self-assessment.

On this subject, NIOSH observes that:

> Job-specific routine bioassay samples were required across many site locations. The locations, the analytes for these locations, and the personnel participating in the Routine Bioassay Sampling Program varied in the procedures between 1971 and 1999. [NIOSH, 2019a, p. 34]

As noted in SC&A's finding 1 of its response to RPRT-0092, while there is provision in DuPont procedures for job-specific bioassays, there is no evidence to date that SWPs or job plans for the DuPont era (1972–1990) contained any requirements or indications for job-specific bioassays or that such bioassays were performed consistently (SC&A, 2019). As the 1998 findings of the FEB and subsequent WSRC review indicate, shortfalls in this characterization process remained into the late 1990s.

SC&A question 2: Completeness of pre-March 1999 bioassays

SC&A (2018, p. 4) asked:

> If WSRC instituted such a policy in March 1999 requiring the RCOs [Radiological Control Operations] to base bioassay monitoring on actual, updated workplace characterization versus expert judgment or longstanding facility knowledge, how incomplete were bioassays (including RWPs) prior to this date with regard to appropriately targeted radionuclides?

Beyond a reiteration of WSRC's approach to "Defense in Depth" radiological monitoring, NIOSH noted:

> Dose reconstruction by NIOSH uses all bioassay data from SRS and, where necessary, uses ratios of expected radionuclides to address intakes that were not measured by the site. Due to the ingrowth of ^{241}Am in ^{241}Pu, it would be expected in any aged plutonium sources. Particular to the characterization results showing ^{241}Am as providing more than 10% of the dose in locations not previously established for routine Am/Cm/Cf bioassay monitoring, the ^{241}Am contribution to

> the dose can be calculated for these locations using estimates of the age of the ^{241}Pu present, as has been calculated at other sites. [NIOSH, 2019a, p. 35]

SC&A accepts this justification for the WSRC operating era (pertaining to Am-241 monitoring after 1990) but, for reasons stated earlier, rejects it for the DuPont era, when an updated, comprehensive characterization was not performed, according to the DOE Tiger Team assessment (DOE, 1990).

SC&A question 3: Worker enrollment in bioassay programs

SC&A (2018, p. 4) asked:

> How does this impact dose reconstruction with sufficient accuracy if workers were incorrectly enrolled in bioassay programs, with potential exposure to key radiological sources not evaluated?

NIOSH's responded:

> There is no indication workers were enrolled incorrectly in the bioassay programs. The March 1999 change in policy by SRS does not impact the accuracy of dose reconstruction by NIOSH. In addition, coworker models can be used to estimate exposures for unmonitored workers.
>
> The issues discussed by SC&A relate solely to the collection of samples under the Routine Bioassay Sampling Program.
>
> The Special Bioassay Sampling Program was designed to assess inadvertent intakes of radioactive material that could exceed 100 millirem to the worker (WSRC 1990[b], p. 36). Workers with suspected or confirmed uptakes of radionuclides were monitored under the Special Bioassay Sampling Program. New requirements for routine bioassays do not indicate that workers in those areas were previously "incorrectly enrolled." They were enrolled in the Routine Bioassay Program according to the requirements in place at that time. [NIOSH, 2019a, p. 36]

As noted by NIOSH in section 4 of RPRT-0091, Am-241 was a radionuclide of concern in building 221-F but was not listed as a required analyte for routine bioassay. Therefore, 221-F workers were not presumably enrolled for routine bioassay for Am-241 along with plutonium. However, as explained by NIOSH, this is mitigated by the annual lung count required of facility workers, which enabled any positive plutonium intake to be evaluated for the presence and quantity of americium. As noted previously, SC&A accepts this explanation; however, in our view, this still constitutes lack of worker bioassay enrollment. Prior to implementation of the more comprehensive, analysis-based characterization process documented in Farrell and Findley (1999), there could have been more workers not enrolled for radionuclides relevant to their workplaces, but it is not feasible to gauge the extent of that gap given the absence of job plans and SWPs during the DuPont era (it may be more feasible for 1991–1998). The balance of the NIOSH response references WSRC procedures for the Special Bioassay Sampling Program, which differs from the RWP or job plan based job-specific bioassay program.

SC&A question 4: Facility source term characterization and adequate internal dose

SC&A (2018, p. 4) asks:

> What is the significance of an apparent lack of ongoing facility source term characterization to adequate internal dose monitoring during the 1990s with the advent and growth of new activities and programs involving new and complex radiological sources, e.g., decontamination and decommissioning (D&D), solid waste management, environmental cleanup, and SRTC?

NIOSH responds that:

> The March 1999 sitewide source term characterization did not affect the adequacy of SRS to monitor workers for internal dose. It did change urine bioassay requirements for the Routine Bioassay Program, however the Routine Program was implemented in excess of the DOE regulatory requirements. No worker at SRS met the 10 CFR Part 835 definition for bioassay monitoring. [NIOSH, 2019a, p. 36]

SC&A finds this response to not be responsive to the question. The answer focuses on the 1999 guidance and the impact it had on source-term characterization but does not address the implications of a lack of such an analytic, comprehensive approach for prior years in the 1990s when SRS was undergoing the major operational changes noted. As emphasized by WSRC (1998), in earlier years, some SRS facilities confronted new missions and operational changes that involved "a wide array of radioactive materials, some of which may not be encountered in the typical radiological work environment by workers in those areas" (WSRC, 1998, p. 2).

More to the point is the response of the WSRC Manager of Internal Dosimetry during the 1990s, Thomas LaBone, who responded to the following question in a written response to SC&A interview questions dated October 6, 2017 (LaBone, 2017):

SC&A interview question:

> To what extent did this deficient RWP source term review process [as detailed in Morgan (1999)[6]] extend to job-specific RWPs, and in the larger sense, how much broader was this issue (improper bioassay enrollment) in terms of other radionuclide source terms on a site-wide basis in prior years (e.g., 1989– 1999)? Did WSRC review prior RWPs to ascertain status on this question, or to address potential missed dose from americium and other radionuclides due to inadequate enrollment reviews?

Response (partial):

[6] Morgan (1999) is a WSRC interoffice memorandum dated November 2, 1999, from C. R. Morgan to M. D. Matheny regarding "Response to the Compilation of PAAA Internal Dosimetry Issues," detailing WSRC's review of the 31 general deficiencies cited by the DOE Office of Enforcement and Investigation as part of its "120-day suspension of PAAA enforcement actions for issues associated with contractor Internal Dose Evaluation Programs (IDEPs)" (p. 1).

> I think that when SRS moved from the production phase to the D&D phase in the 1990's there were changes in the source terms that were not fully anticipated because of the change in mission. This, combined with a change in the way we specified routine bioassay programs was most likely the cause of the problem with the routine program you cited with Am-241. I think ESH-RPS-2005-00054 has a good discussion of this issue.[7] However, we did not have this problem for special samples, where we always required specification of the source term by analysis of the contamination that triggered collection of the sample. [LaBone, 2017, p. 27]

SC&A considers this a more contemporaneous explanation of the causes and implications of the Am-241 characterization concern as it relates to the routine bioassay program, specifically, the identification of radionuclides of concern for RWPs.

SC&A question 5: Ramifications of missed radionuclides

SC&A (2018, p. 5) asked:

> If key radionuclides such as americium had been missed, what other sources were not reflected on RWPs over time and what are the ramifications for dose reconstruction with sufficient accuracy for those workers potentially affected?

In its response, NIOSH noted:

> Key radionuclides were not "missed" before 1999 in the Routine Bioassay Sampling Program; there was a change in the methods used to list radionuclides required under the Routine Bioassay Program. The March 1999 change in policy by SRS does not impact the accuracy of dose reconstruction by NIOSH. In addition, coworker models could be used to estimate exposures for any unmonitored workers. [NIOSH, 2019a, p. 37]

SC&A disagrees that the 1999 guidelines were simply "a change in the methods used to list radionuclides required under the Routine Bioassay Program," and that Am-241, as a source term, was not "missed" for MPPF and building 221-F before 1999. The 1999 guidelines were the culmination of a 10-year evolution of SRS policy regarding how radiological source terms were to be identified, characterized, and reflected in the bioassay program. Beginning with the 1990 Tiger Team finding of noncompliance with DOE Order 5480.1, WSRC had proceeded to revamp the manner in which the bioassay radionuclide type and frequency schedule had been maintained under DuPont. In 1990, in response to the Tiger Team, WSRC verified its facility-by-facility source-term characterization and then proceeded to develop a more comprehensive approach as reflected in its first "Internal Dosimetry Technical Basis Manual," WSRC-IM-90-139 (December 1990). Successive editions of this Manual made adjustments to the bioassay sampling frequency

[7] SC&A's January 11, 2018 memorandum noted that the report cited by LaBone, ESH-RPS-2005-00054 (Hadlock, Moxley, & Dean, 2005), was reviewed by SC&A and was found to be essentially a "lessons learned" review, dated March 11, 2005, of experience gained with the WSRC source term characterization program originally implemented 6 years earlier in 1999. SC&A's (2018) memorandum discusses this document in more detail.

tables based on changing operations, source-terms, and experience. These tables contained facility-based radionuclides for bioassay based on the following assessment:

> Many radionuclides may be present in a facility. Waste streams such as those at DWPF [Defense Waste Processing Facility] or other waste treatment facilities may contain on the order of 60 radionuclides. Since it is not practical to design a program for each radionuclide, the radionuclides of concern are determined as follows. All radionuclides in a facility are identified from safety analysis reports (SAR), personal interviews, the open literature, etc. The radionuclides whose radiotoxicity and exposure potential combine to deliver 90% of the dose are considered to be the radionuclides of concern. [WSRC, 1990b, PDF p. 248]

However, it is also noted that the facilities and (and presumably) the operations within those facilities to be included would continue to be selected by Health Protection Operations (HPO) and Health Physics Technology (HPT) personnel:

> The facilities that are included in this section are those selected by HPO and HPT personnel to be of radiological concern. It is understood that other facilities will be added as needed. [WSRC, 1990b, PDF p. 248]

In 1997, it was recognized that the bioassay frequency tables in the 5Q1.1 Manual procedures could be misconstrued, and it was clarified that "being on a routine sampling program does not automatically cover the bioassay sampling requirement specified on the RWP" (Findley, 1997, PDF p. 9). As noted in SC&A's January 11, 2018, memorandum report, the implication from this policy clarification is that improper cross-referencing in WSRC procedures may have led radiological control supervisors to apply routine facility bioassay requirements to RWPs that entailed radiological source terms different from those of routine work.

In 1998, the issue of specifying bioassay requirements on RWPs was further clarified, with notice that WSRC staff were "working in tandem on a pilot program to establish guidelines in determining the radionuclide(s) of concern for urine samples in the Burial Ground" (WSRC, 1998, page 1). This memorandum goes on to note that a review by the FEB of SRS solid waste management facilities identified concerns over how radionuclides were identified for urinalysis on RWPs. Specifically, curium was identified as a principal waste constituent but was not specified on RWPS for solid waste management workers. While a followup investigation resolved the concern, WSRC identified the underlying concern as one of "how the Radiological Control organizations determine which radionuclide(s) of concern are identified on the RWP and how these determinations are made" (WSRC, 1998, pp. 2–3). WSRC indicated that "to resolve this concern, guidelines that will aid the Radiological Control organizations in prescribing RWP urine bioassay sampling will be developed for each facility" (WSRC, 1998, p. 3).

These guidelines were issued in a memorandum from W. E. Farrell and W. M. Findley to M. D. Matheny on March 10, 1999 (Farrell & Findley, 1999), which noted:

> Historically, bioassay requirements were identified by the Radiological Control Operations (RCO) organization through facility process knowledge (i.e., safety analysis documentation), procedural guidance and professional judgement. The

> methodology discussed in this memorandum was used by Health Physics Technology (HPT) to update and/or reverify facility specific radionuclides of concern for bioassay program compliance. The routine urine bioassay program is based on the premise that monitoring must be performed *a posteriori* (after the fact) to verify that radioactive materials are not being internally deposited in workers. . . .
>
> When a urine sample is submitted, it is imperative that the correct analysis be requested. This requires that the radiological source term be well know and characterized. [Farrell & Findley, 1999, pp. 1–2]

Contrary to NIOSH's response, noted earlier, that no key radionuclides were missed and that the 1999 guidelines were simply a relisting of bioassay frequencies, the WSRC procedural reviews and revisions of the 1990s served to apply lessons learned and operational experience to a much more comprehensive process of accurately identifying radionuclides of concern when determining RWP requirements.

Conclusion

SC&A concludes that NIOSH's explanation regarding the two SRS facilities for which unrecognized Am-241 sources were not included in RWP preparation, as originally noted in a 1998 WSRC self-assessment (Morgan, 1999), serves to mitigate our original concern noted in SC&A's presentation before the Advisory Board on November 14, 2017. As discussed in RPRT-0091, the MPPF did not actually begin processing americium-containing solutions until the 2004–2005 timeframe, and building 221-F, while not including Am-241 as one of the radionuclides of concern for urinalyses, did have an annual chest count through which Am-241 would have been detected whenever a positive plutonium reading was made.

While these circumstances provide a pathway for dose reconstruction of potential Am-241 doses for workers in these facilities, they do not resolve the larger question of whether source-term characterization in support of facility operations that underwent rapid change and diversification in the 1985–1998 timeframe were sufficiently accurate and complete to support job plan and RWP preparation. While a comparison of facility and job-specific source terms before and after the 1999 guidelines may be possible as one means to resolve this question, the lack of complete job plans prior to 1991 (when a formal RWP system was put in place) and the evolving nature of SRS source-term characterization, culminating in the 1999 guidelines, makes such a comparison problematic. However, the fact that DuPont, and subsequently WSRC, failed to carry out an RWP program with required job-specific bioassays until 1991, despite procedures requiring its implementation, makes the question of adequate source-term characterization moot for that particular application in that earlier timeframe.

SC&A's overall concern regarding DuPont's procedures for identifying "radionuclides of concern" and reflecting them in job plans and required job-specific bioassays is addressed in finding 2 of SC&A's recently issued report, "Review of ORAUT-RPRT-0092, Revision 00, 'Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site'" (SC&A, 2019).

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