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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

SC&A's Evaluation of Revision 01 of ORAUT-RPRT-0090: Exotic Radionuclides Produced by Oak Ridge National Laboratory

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
Am	americium
Bk	berkelium
Cf	californium
Cm	curium
D&D	decontamination and decommissioning
DR	dose reconstruction
ER	evaluation report
HP	health physics
MAP	mixed activation product
MFP	mixed fission product
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH DCAS Claims Tracking System
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
ORNL	Oak Ridge National Laboratory
RaLa	radioactive lanthanum
Ru	ruthenium
SRDB	Site Research Database
WBC	whole body counter
WG	work group
X-10	Oak Ridge National Laboratory

1 Introduction and Background

In March 2018, the National Institute for Occupational Safety and Health (NIOSH) issued ORAUT-RPRT-0090, revision 00, "Monitoring Feasibility Evaluation for Exotic Radionuclides Produced by the Oak Ridge National Laboratory Isotopes Division" (ORAUT, 2018; "RPRT-0090"). This report evaluated the internal monitoring capability of Oak Ridge National Laboratory (ORNL, X-10) for radionuclides that were produced by the Isotopes Division and its predecessors from 1955 to 1988. In April 2018, the Advisory Board on Radiation and Worker Health (ABRWH, "Board") tasked SC&A to review RPRT-0090 (ABRWH, 2018). In October 2018, SC&A submitted SCA-TR-2018-SEC004, revision 0, "SC&A's Evaluation of RPRT-0090, 'Monitoring Feasibility Evaluation for Exotic Radionuclides Produced by the Oak Ridge National Laboratory Isotopes Division'" (SC&A, 2018).

In June 2020, NIOSH issued "NIOSH Response to SC&A Evaluation of SEC-00189 ORNL X-10 ORAUT-RPRT-0090" (NIOSH, 2020). In January 2021, SC&A responded with SCA-TR-2020-SEC007, revision 0, "Review of NIOSH Response to SC&A Comments on ORAUT-RPRT-0090 re Monitoring Feasibility Evaluation for Exotic Radionuclides Produced by the Oak Ridge National Laboratory Isotopes Division" (SC&A, 2021). This document was discussed at the June 30, 2021, ABRWH ORNL (X-10) Work Group (WG) teleconference meeting (ABRWH, 2021a), at which the WG closed several of SC&A's (2018) findings and observations.

As a result of those discussions and NIOSH and SC&A response papers, NIOSH issued revision 01 of RPRT-0090 in March 2023 (ORAUT, 2023). This report provides SC&A's assessment of that revision to determine to what degree it addresses any open findings and observations from SC&A (2018).

2 Previous Findings and Observations

SC&A's review of revision 00 of RPRT-0090 (SC&A, 2018) resulted in seven findings and six observations. The WG closed four findings (1, 2, 6, 7) and four observations (1, 2, 3, 5) at its June 30, 2021, meeting (ABRWH, 2021a) and left the remaining three findings (3, 4, 5) and two observations (4, 6) open pending NIOSH actions. The issues and WG decisions are summarized in a presentation the WG made at the August 19, 2021, Board meeting (ABRWH, 2021b).

The following sections focus on NIOSH's responses in revision 01 of RPRT-0090 to the open findings and observations and also list all the findings and observations for convenience and completeness. In addition, several of the findings and observations are grouped together for convenience because they cover similar topics.

2.1 Findings 1 and 7 (closed)

Finding 1, "Scope of RPRT-0090 needs to be clearly defined," states (SC&A, 2018, p.11):

> SC&A finds that the scope of RPRT-0090 needs to be clarified in terms of whether (and how) it is meant to encompass the "reserved" portion of the ER for "cyclotrons, accelerators, and reactors" and whether NIOSH intends to address the full scope of radionuclides involved in waste management (including D&D [decontamination and decommissioning]), site-wide construction, and maintenance.

Finding 7, "Unclear treatment of post-1988 monitoring capability during abandonment, deactivation, and decontamination and decommissioning phases," states (SC&A, 2018, p. 35):

> After radionuclide production ended, the adequacy of monitoring and feasibility of assigning intakes from the storage, disposal, and D&D of the facilities has not been addressed. This issue is especially important for the ORNL Isotopes Division because it processed and concentrated unusual radionuclides that would not be encountered during the normal D&D process.

2.1.1 RPRT-0090, revision 01, addresses findings 1 and 7

Several of NIOSH's responses are informed by the statement of scope in section 2.0 of RPRT-0090, revision 01 (ORAUT, 2023, p. 6):

> This report evaluates the capability of the ORNL HP program to monitor all materials that were produced and handled by the Isotopes Division, regardless of production location, in order to determine if bioassay technology deficiencies existed that could result in improper monitoring. The scope of this report is limited to isotope production activities; it excludes treatment of decontamination and decommissioning, site-wide construction, and maintenance activities that may encompass these same facilities. Although this report identifies potential dose reconstruction challenges, it is not an evaluation of whether a co-exposure model approach could be developed for every radionuclide.

2.1.2 SC&A response concerning findings 1 and 7

During the June 30, 2021, WG meeting (ABRWH, 2021a), NIOSH clarified the scope and intent of RPRT-0090 as limited to only activities of the ORNL Isotope Division, and the WG closed findings 1 and 7. SC&A reviewed the additional text in section 2.0 of RPRT-0090, revision 01, and confirmed it is consistent with the discussions.

2.2 Finding 2 and observation 1 (closed)

Finding 2, "Incomplete radionuclide and radioisotope facility inventory," states (SC&A, 2018, p. 14):

> A sampling of the radionuclides listed in Table 7-2 [summary of monitoring capabilities by radionuclide in inventory] found a few missing when compared with operational and customer records. Likewise, a few ORNL facilities that historically handled radioisotopes are also not included in those cited and addressed in RPRT-0090. Given the operational diversity of ORNL accelerator and reactor operations, consideration should be given to an inventory scope that encompasses isotopic source terms broader than that of the Isotope Division.

Observation 1, "Inventory discrepancy," states (SC&A, 2018, p. 12):

> A sampling of some of the inventory of the radionuclides for the early years indicated some discrepancies in inventory between Table 7-2 in RPRT-0090 and NIOSH's X-10 Inventory spreadsheet.

2.2.1 RPRT-0090, revision 01, addresses finding 2 and observation 1

In RPRT-0090, revision 01, NIOSH added the following text to section 6.0, "Inventory Development" (ORAUT, 2023, p. 18):

> The resultant inventory represents materials produced by the Isotopes group as opposed to a more general inventory of materials present at the site. For example, individual fission product radionuclides contained within unprocessed reactor fuels are not included within the inventory quantities.

2.2.2 SC&A response concerning finding 2 and observation 1

SC&A notes that the scope of RPRT-0090, as stated in the title of the report and clarified in revision 01, appears appropriate because it limits consideration to those exotic isotopes produced by the ORNL Isotopes Division and only considers the radionuclides produced. The WG closed finding 1 and observation 2 at its June 30, 2021, meeting (ABRWH, 2021a).

2.3 Finding 3 (open)

Finding 3, "Attachment A in vitro bioassay methods lack information about actual implementation," states (SC&A, 2018, p. 36):

> In vitro bioassay methods are outlined in Attachment A, but it does not include any discussion or references regarding their actual field implementation. The

> exclusion of comparable in vivo monitoring methods makes a review of ORNL monitoring capability incomplete.

Finding 3 was discussed at the June 30, 2021, WG meeting and remains open pending the development of a co-exposure model or other method acceptable to the WG.

2.4 Finding 4 (open)

Finding 4, "Feasibility of monitoring 28 radionuclides not adequately addressed," states (SC&A, 2018, p. 24):

> While the 28 radionuclides were discussed in Section 7.2 and some of their characteristics were listed in Tables 7-4, 7-5, and 7-6 of RPRT-0090, the feasibility of monitoring for intakes for DR purposes was not completely addressed, particularly given the lack of routine bioassays in the earlier years. Methods for accounting for the lack of monitoring of these radionuclides need to be addressed in more detail, and an acceptable resolution derived. SC&A finds that it is not possible at this time to validate implementation without further onsite review, including document review and interviews with health physicists of the time period involved.

2.4.1 RPRT-0090, revision 01, concerning finding 4

RPRT-0090, revision 01, added the following text to section 8.0, "Summary" (ORAUT, 2023, p. 45):

> NIOSH developed an ORNL radionuclide inventory by reviewing shipping records, sales reports, and selected logbooks. The inventory was compared to available bioassay data and available bioassay methods. This study did not evaluate if ORNL workers were properly monitored but rather if bioassay technology deficiencies existed that would result in improper monitoring.
>
> The ORAU Team compared the available bioassay date from the ORNL internal monitoring database with the data provided by ORNL as contained within Energy Employee Occupational Illness Compensation Program Act claimant files. With the exception of gross beta analysis (results of which seem to be missing from the ORNL database between 1955 and 1959), the sample frequency in the ORNL and NOCTS datasets are comparable, although the NOCTS data files tend to be more complete. The results are consistent with the conclusion of the ORNL Internal Dosimetry staff that the database is incomplete and might be missing up to 25% of the bioassay samples [ORAUT, 2013], albeit comparison between NOCTS and the ORNL database indicates a slightly lower value based on the qualitative evaluation in this document.

Section 8.0 goes on to say:

> The combination of the inventory and radiological dose coefficients for these 28 radionuclides allowed the development of bounding potential intakes (see Table 7-6) for these radionuclides. These bounding intakes could be used as the basis for a plausible estimation of dose from these radionuclides.

2.4.2 SC&A response concerning finding 4

The NIOSH response in RPRT-0090, revision 01, limits the report's scope to exclude the issue of whether the ORNL workers were properly monitored but rather focuses on monitoring technology capability (not dose reconstruction feasibility as a whole). SC&A notes that key language has been updated or removed in revision 01 to clarify that the scope is not to determine the feasibility of dose reconstruction, but rather the technological capability to monitor exposed workers for the exotic radionuclides. Per discussions during the WG's June 30, 2021, meeting, the question of dose reconstruction feasibility remains open pending a full co-exposure assessment and model development or some alternative method acceptable to the WG.

2.5 Finding 5 and observation 6 (open)

Finding 5, "1955 and 1956 intakes may not be bound by earlier coworker data," states (SC&A, 2018, p. 26):

> Assessment of RaLa [radioactive lanthanum] radioiodine releases at X-10 indicates the highest annual releases occurred during the campaign to process Hanford slugs during 1956. Therefore, the radioiodine production and releases during the years used for coworker development (1947–1949) do not appear to bound the production throughput, at least during 1956 and possibly 1955.

Observation 6, "Additional RaLa production information should be provided," states (SC&A, 2018, p. 26):

> NIOSH should provide an evaluation and discussion of any potential differences in exposure potential between commercial radioiodine production and the radioiodine produced via the RaLa operation to justify the extrapolation of exposures occurring during the years 1947–1949 to the unmonitored period (1955–1962).

2.5.1 RPRT-0090, revision 01, concerning finding 5 and observation 6

RPRT-0090, revision 00, attachment C, "Dose Reconstruction Approach for Iodine," discusses the use of thyroid monitoring data collected from 1947 through 1949 for later years. Revision 01 of the report removes attachment C and revises section 7.1 to refer to a separate document "specifically targeting assignment of internal dose from radioiodine exposure" (ORAUT, 2023, p. 40).

2.5.2 SC&A response concerning finding 5 and observation 6

SC&A reserves comment on the RaLa radioactive iodine issue until it reviews NIOSH's planned standalone report on radioiodine exposure. SC&A recommends that the finding and observation remain open until that time.

2.6 Observation 4 (open)

Observation 4, "Use of gross beta or gamma count data could result in underestimate of assigned dose," states (SC&A, 2018, p. 19):

> Using gross beta or gamma count data without knowledge of the radionuclide the counter was calibrated with and the radionuclides in the bioassay sample could result in assigning the incorrect radionuclide and radioactivity content because of different counting efficiencies for the different energy of beta particles and gamma photons. Has this issue been addressed for DR for ORNL claimants? Additionally, bioassay data for at least one beta-emitting radionuclide (Ru-106) could not be located for several years that Table 7-2 indicated it was available.

2.6.1 RPRT-0090 revision 01 addresses observation 4

Table 7-3 of RPRT-0090, revision 01, revises the entries for ruthenium (Ru)-106 for the years 1975, 1978, and 1986 through 1988 to indicate that, for those years, the radionuclide was present in the inventory and a bioassay method was available to detect the radionuclide, but no sample results for that bioassay method were available.

Also, NIOSH added to RPRT-0090, revision 01, the following text in sections A.1.2, A.1.3, and A.1.4 (ORAUT, 2023, pp. 56–57):

> Note: Adjustment of results based on the beta emission energy for a specific radionuclide may be necessary when the emission energy for the suspected radionuclide is sufficiently different than the emission energy for the calibration source. Henley reported that gross beta counting systems were calibrated using Sr-90 [Henley, 1978, p. 65].

2.6.2 SC&A response concerning observation 4

SC&A notes that RPRT-0090, revision 01, treats the Ru-106 concern and provides additional dose reconstruction guidance related to calibration. NIOSH's response is acceptable and SC&A recommends that this observation be closed.

2.7 Observation 5 (closed)

Observation 5, "The results in Table 7-6 depend on inventory used," states (SC&A, 2018, p. 22):

> As outlined in Observation 1, there appear to be some discrepancies in the inventory used by NIOSH compared to those provided to SC&A for evaluation of RPRT-0090. These discrepancies change a few of the results of Table 7-6, as illustrated in Table 3 of this report.

2.7.1 RPRT-0090, revision 01, concerning observation 5

After NIOSH conducted additional research on the radionuclides in table 7-6 of RPRT-0090, revision 01 revises the row for tellurium-121 to indicate no inventory data are available for one or more years for this radionuclide (ORAUT, 2023, p. 43, table 7-6).

The WG closed this observation at its June 30, 2021, meeting (ABRWH, 2021a).

2.7.2 SC&A response concerning observation 5

SC&A conducted further research for the radionuclides in table 7-6 when information was incomplete. NIOSH provided information on the inventory discrepancies in table 3 of its 2020 response paper (NIOSH, 2020, p. 12). SC&A analyzed the additional data and references and concurred with NIOSH's response. SC&A finds that this observation has been addressed as indicated by its closure by the WG at its June 30, 2021, meeting.

2.8 Finding 6 (closed)

Finding 6, "Adequacy and implementation of in vivo bioassay program not addressed," states (SC&A, 2018, p. 33):

> Information is lacking for the actual implementation of the ORNL *in vivo* program, including what and how radionuclides were monitored in practice, what and how workers were identified and included for counting, and how capability to monitor for MAPs, MFPs, and exotic radionuclides paced both technology developments and onsite monitoring practice (e.g., routine vs. nonroutine monitoring). SC&A recommends that the Work Group request a review of available records, particularly internal dosimetry program records and WBC nuclide libraries, and scheduling of interviews with appropriate ORNL dosimetry staff.

Finding 6 was discussed at the June 30, 2021, WG meeting, where it was closed and subsumed under finding 3.

2.9 Observation 2 (closed)

Observation 2, "Specific alpha-emitting radionuclide needs to be identified for DR," states (SC&A, 2018, p. 37):

> The specific radioisotope monitored is not always presented in NIOSH's X-10 Database as it generally is in the NOCTS files. Gross alpha results could be applied to many radionuclides. Is the information on the original bioassay cards available in the X-10 Database, and will the X-10 Database be used in DR or coworker model development?

Observation 2 was discussed at the June 30, 2021, WG meeting, where the WG closed it.

2.10 Observation 3 (closed)

Observation 3, "Trans-plutonium radionuclides may need further analysis," states (SC&A, 2018, p. 37):

> SC&A is concerned that assigning trans-plutonium gross alpha counting results as Am-241 intakes without consideration of other potential trivalent alpha-emitting actinides (such as Bk-249, Cf-252, Cm-242, Cm-244, etc.) and their individual radiotoxicity could result in underestimating the internal dose. It could be beneficial to determine if assigning the intake as Am-241 is claimant favorable, considering the exotic trans-plutonium radionuclides at ORNL.

Observation 3 was discussed at the June 30, 2021, WG meeting, where the WG closed it.

3 Summary and Conclusions

NIOSH issued ORAUT-RPRT-0090 in March 2018, which evaluates the capability of ORNL's internal monitoring for exotic radionuclides produced by the Isotopes Division (ORAUT, 2018). SC&A submitted a review of RPRT-0090 in October 2018, which identified seven findings and six observations (SC&A, 2018). As a result of discussions among the X-10 WG, NIOSH, and SC&A, the WG closed findings 1, 2, 6, and 7 and observations 1, 2, 3, and 5 during its June 30, 2021, meeting. During this WG meeting, NIOSH committed to making various revisions to RPRT-0090.

In this report, SC&A reviews revision 01 of RPRT-0090 (ORAUT, 2023) and confirms that the revisions are consistent with the discussions from the WG meeting that led to the closure of findings 1–2 and 6–7 and observations 1–3 and 5.

SC&A has the following recommendations about the remaining findings and observations:

- **Findings 3 and 4** remain in progress pending NIOSH's development of a co-exposure model or an alternative method acceptable to the WG. SC&A notes that the question of monitoring feasibility is unanswered.

- **Finding 5 and observation 6** remain in progress pending NIOSH's planned standalone report on radioiodine exposure.

- **Observation 4:** After reviewing the text NIOSH added to RPRT-0090, revision 01, regarding the Ru-106 concern and dose reconstruction guidance related to calibration of gross beta counting systems, SC&A recommends closure.

4 References

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