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SC&A'S EVALUATION OF NIOSH'S RESPONSE DATED MARCH 31, 2011, TO SC&A'S SECOND WHITE PAPER ON RECYCLED URANIUM (SEC ISSUE #3) AT FERNALD

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ABBREVIATIONS AND ACRONYMS

ABRWH or Advisory Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
DCAS	Division of Compensation Analysis and Support
DOE	U.S. Department of Energy
DR	dose reconstruction
EEOICPA	Energy Employees Occupational Illness Compensation Act of 2000
EM	Environmental Management
FMPC	Feed Material Production Center
GDP	Gaseous Diffusion Plant
LEU	Low Enriched Uranium
M&O	Management and Operations
MgF_2	magnesium fluoride
NIOSH	National Institute for Environmental Safety and Health
NLO	National Lead of Ohio
POOS	Plutonium Out Of Specification
ppb	parts per billion
ppm	parts per million
PUREX	Plutonium Uranium Extraction
REDOX	oxidation-reduction
RU	Recycled Uranium
SC&A	S. Cohen and Associates
SEC	Special Exposure Cohort
SRDB	Site Research Database
SRS	Savannah River Site
TRU	transuranic
UNH	Uranyl nitrate hexahydrate
UF_4	uranium tetrafluoride
UO_3	uranium trioxide

1.0 INTRODUCTION

1.1 NIOSH Response dated March 31, 2011

On April 17, 2011, the National Institute for Occupational Safety and Health (NIOSH) provided a response to SC&A's second white paper on recycled uranium (RU) at Fernald in an e-mail by Mark Rolfes. That e-mail contained an attachment titled, *NIOSH Response to 2-11 SCA RU whitepaper.docx.* Below is an historical summary of the discussions and white paper exchanges regarding the RU issue at Fernald; NIOSH's response of March 31, 2011; and SC&A's evaluation of NIOSH's response.

1.2 Historical Milestones Leading Up To This Report

During the Fernald Work Group meeting held on October 28, 2008, SC&A was tasked with reviewing the NIOSH white paper on RU entitled, *Dose Reconstruction Considerations for RU Contaminants at Fernald* (NIOSH 2008). The direction provided by the Advisory Board on Radiation and Worker Health (ABRWH or Advisory Board) stated that SC&A should focus on the appropriateness of the default values selected for RU contaminants [Pu-239/240 (referred to herein as Pu-239), Neptunium-237 (Np-237), and Technecium-99 (Tc-99)], and whether the selected values are bounding for all workers for all time periods. SC&A's white paper on this issue entitled, *SC&A's Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald: Commentary on the NIOSH White Paper* (SC&A 2009), identified 11 deficiencies (findings) in the NIOSH white paper, which were the subject of extensive discussions at the January 29, 2010, Work Group meeting. SC&A (2009) and the discussions provided at the January 29, 2010, meeting transcript (ABRWH 2010) thoroughly describe SC&A's concerns regarding RU. During the January 2010 Work Group meeting, NIOSH stated that it was not prepared at that time to address the various issues raised, but agreed to prepare a response.

Prior to the November 9, 2010, Work Group meeting, NIOSH submitted the report, *Response to SC&A Findings related to the White Paper on Recycled Uranium at Fernald – October 2010*, (NIOSH 2010), which provided NIOSH's position on each of the 11 findings in SC&A (2009). The 11 findings and NIOSH's responses to these findings were the subject of intensive discussions at the November 9, 2010, meeting. Two principal unresolved issues that emerged from that meeting prompted the Advisory Board's request for a second white paper. First, SC&A provided a compelling argument as to why the 19 subgroup process means derived in the U.S. Department of Energy (DOE) Ohio Field Office Report (DOE 2000b) and reported in Table 5 of NIOSH (2008) do not provide a firm basis for bounding defaults for transuranics (TRU) and fission products. Second, SC&A's preliminary review of the dust collector data reported in Appendix B of NIOSH (2008) indicated that the NIOSH default values may not be bounding for some classes of workers in some facilities during the proposed Special Exposure Cohort (SEC) period.

SC&A's second white paper on recycled uranium, *SC&A Review of Issues Related to Reconstruction of Doses for Workers Exposed to Recycled Uranium at Fernald – A Second White Paper* (SC&A 2011a), was transmitted to the Work Group prior to the February 9, 2011,

Work Group meeting. That paper identified nine new findings that supported our position regarding the questionable basis for NIOSH's proposed RU defaults, and that some categories of workers were exposed to TRU and fission product levels in excess of the NIOSH defaults. The issues were discussed in detail at the February 9, 2011, Work Group meeting. At that meeting, NIOSH was tasked to respond to SC&A (2011a) prior to the next Work Group meeting, scheduled for April 19, 2011.

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

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

At the Advisory Board meeting held in St. Louis, Missouri, May 24–26, 2011, SC&A presented the status of our six main SEC findings regarding Fernald. Part of that presentation focused on our preliminary observations on NIOSH (2011). At the conclusion of the presentation, SC&A was tasked by the Advisory Board to provide a formal response to NIOSH (2011). This document fulfills that request.

2.0 SC&A'S SEC ISSUE #3 – RECYCLED URANIUM

SEC Issue #3 can be summarized by the following statement: **Default concentrations (on U mass basis) of Pu-239, Np-237, and other isotopes associated with RU at Fernald may not be bounding for some classes of worker activities, buildings, and time periods.**

The following is a summary of SC&A's findings from SC&A (2011b). The findings can be grouped into two main categories:

(1) Those relating to whether the NIOSH defaults are bounding for all classes of workers at Fernald for the period during which RU was received, handled, and processed (1953–1989)

(2) Those relating to the veracity of the basis documents that underlie the NIOSH defaults

Detailed discussions of the findings are found in SC&A (2011b) and are not replicated here. However, the relevant sections of SC&A (2011b) are identified.

Finding #1: Questionable basis for NIOSH presumptions regarding the integrity of Fernald radiation safety programs prior to 1986 **(SC&A 2011b, pp. 21–27):**

> *The DOE RU reports and related historical references indicate that prior to 1986, the radiation safety program at Fernald was probably not adequate to control potential exposures from contaminants in RU. In all likelihood, the 1986 changes were implemented by the new M&O contractor in response to problems encountered during RU processing in the preceding years. This raises concerns regarding NIOSH's reliance on the integrity of such programs as assurance that their defaults were not exceeded during the proposed SEC period. This is not only of concern during the early years of RU processing, but also during the 6 years that had elapsed from the time the most contaminated RU material was received in 1980 until the new program elements were implemented.*

Finding #2: Questionable basis for NIOSH default plutonium concentration **(SC&A 2011b, pp. 27–29):**

> *A formal specification for maximum transuranic and fission product contaminants in uranium recycled material had probably not existed either within or between sites. In fact, the only formal limit adopted by the Atomic Energy Commission (AEC) for RU was adopted in 1971 to accommodate commercial fuel shipments to the gaseous diffusion plant (GDP). The fact that there are several orders of magnitude of variability in the 4,000 analytical results reported for Pu-239 in DOE 2000b raises concerns as to NIOSH's reliance on the Hanford 'working specification' of 10 ppb as the basis for their default plutonium concentration. SC&A believes that a re-analysis of the data to determine if there are classes of workers that are not sufficiently bounded by the current methodology would be highly beneficial.*

Finding #3: NIOSH provides no clear basis for the choices of 3,500 and 9,000 ppb U for Np-237 and Tc-99 defaults **(SC&A 2011b, pp. 30–32):**

> *NIOSH indicates that data from Table 5 of their RU white paper were used to develop the default activity ratios for use in the absence of specific bioassay data for workers involved in any of these process subgroups. However, it is not clear to SC&A how the values of 3,500 and 9,000 ppb U for Np-237 and Tc-99 (and the ratios of 35 and 90 for Np/Pu and Tc/Pu) were derived from these subgroup means.*

Finding #4: DOE 2000b is questionable as the basis for the NIOSH defaults; Source data should be reviewed in the context of an SEC Petition **(SC&A 2011b, pp. 33–43):**

> *The DOE 2000b report for RU data is neither comprehensive nor reliably representative and rigorous in its scrutiny of data validity. Clearly the subgroups listed in Tables ES-5A, 5C and 5D are not sufficiently detailed to reflect the wide range of RU sources that would result from analysis of the permutations of*

processing facility, process operations, time of operation and fuel/target type. It is incumbent on NIOSH to review the source data for its adequacy in bounding worker doses in an SEC context.

***Finding #5: Gaps and limitations in the dust data render them questionable as a basis for establishing default levels of contaminants in RU for the SEC period* (SC&A 2011b, pp. 44–49):**

SC&A believes that the 1985 dust collector data alone are not adequate as a basis for establishing default levels of RU contaminants. However, we believe that they have some utility in determining whether the NIOSH defaults are bounding for all classes of workers at Fernald during the proposed SEC period and potentially for estimating intakes for some classes of workers in the 1980s.

***Finding #6: Dust data do not support NIOSH defaults for some classes of workers in some facilities* (SC&A 2011b, pp. 49–53):**

The Plant 1 and Plant 5 dust data, while limited in space and time, tend to support the concentration and persistence of RU contaminants in those facilities, and suggest that some classes of workers were potentially exposed to levels of RU contaminants in excess of the NIOSH defaults.

***Finding #7: Boundary air concentrations of Pu do not support NIOSH defaults and are consistent with elevated levels observed in dust collector data* (SC&A 2011b, pp. 53–57):**

Elevated plutonium ratios in site boundary air measurements appear to correlate with the onset of processing of the highly contaminated Paducah tower ash shipments and are consistent with the elevated levels in Plants 1 and 5. Note also that one would expect boundary air concentration ratios to be lower than Plant 1 and 5 source effluents due to dilution with uncontaminated uranium from other stacks.

***Finding #8: The 1989 air sampling data for Plants 4 and 8 do not support the NIOSH default levels as bounding. Potentially significant worker doses could have resulted from off-normal events* (SC&A 2011b, pp. 57–60):**

The statements in Bassett et al. 1989 indicate that the limited set of 24-hour air collections do not reflect incidents with high exposure potential such as the spills, hydrofluorination bank failures in Plant 4 or furnace temperature excursions in Plant 8, as identified in DOE 2000b (Table D.1-15). While measured air concentrations were low, the mass fractions of Pu and Np were high, exceeding the defaults in several instances. During high dust loading events, these levels could result in significant exposures to workers.

***Finding #9: The Hanford UNH data from the early 1970s suggest that the working specification for Pu was exceeded on a frequent basis with some batches much higher than the NIOSH default* (SC&A 2011b, pp. 60–62):**

> *While it is recognized that this material could have been down-blended at later steps in production, it remains unclear whether batches of UO_3 in excess of the NIOSH default were shipped to Fernald and if so, whether Fernald personnel were aware of it and took precautionary measures*

3.0 SC&A'S SUMMARY OF NIOSH'S MARCH 31, 2011, RESPONSE TO SC&A'S SECOND WHITE PAPER ON RU AT FERNALD

NIOSH 2011 is organized into three major sections: a statement of purpose; general statements and background opinions; and specific discussion and responses to SC&A (2011a). This third section is further subdivided by major issues into three broad categories: a discussion of the viability of the DOE mass balance reports (DOE 2000a, DOE 2000b, DOE 2000c, and DOE 2003); specific RU contaminant defaults; and Fernald radiation safety program deficiencies. NIOSH has grouped SC&A's findings into one of these three issue-based categories and provided a general response to each. The following discussion provides SC&A's responses to each of the categories identified in the NIOSH paper.

3.1 Statement of Purpose

NIOSH indicates in this section that:

> *…the discussion leads to a proposed revision to the present contaminant default dose reconstruction recommendations. The present defaults have been questioned as to whether they actually "bound doses to RU contaminants to all classes of workers to the levels deemed appropriate to dose reconstruction under EEOICPA." At issue is the interpretation of the degree of precision necessary to meet the intent of the quote. The other (and perhaps the issue of greatest concern) is the challenge to the primary sources of RU information and data, the DOE Mass Balance Reports.*
>
> *…The primary objective will be to re-examine existing data and information, coupled with newly retrieved information from the Legacy files, respond in general terms and evaluate the necessity of establishing another set of credible RU contaminant defaults.*

SC&A has one comment regarding the statement of purpose. SC&A also questions whether the NIOSH defaults are bounding in an SEC context. That concern is captured on page 8 of SC&A (2011b) and is replicated here for convenience:

> *The Board also requested that SC&A provide a focused review of available data pertaining to measurements of TRU and fission products in RU at Fernald for their applicability in assessing whether the default levels reported in Table 10 of NIOSH 2008 are bounding in the context of a Special Exposure Cohort (SEC)*

> *petition. As such, our review addresses the ability of NIOSH to bound the RU dose (or estimate a dose more accurately than a bounding dose) for all workers in the proposed SEC class, which extends from 1951 to 1989, the year in which production activities at Fernald ceased permanently.*

3.2 General Statements and Background Opinions

On page 1 of their report, NIOSH lists five general statements to lay the basis for their following recommendations. In summary, NIOSH acknowledges that the data and analysis in SC&A (2011a) has prompted a re-evaluation of the RU defaults and proposes to increase the defaults for Pu, Np-237, and Tc-99. Most importantly, NIOSH proposes to base the new defaults on the 95th percentile of a lognormal fit to the 19 process subgroup data in Appendix F of DOE (2000b). Note that NIOSH's previous reliance on "bootstrap means" of the process subgroup data as derived in DOE (2000b) was a principal source of concern to SC&A. Details of those concerns are provided on pages 35–38 of SC&A (2011b) and Findings 10 and 11 from SC&A (2009), in which SC&A recommends the use of an upper quantile of the lognormal distribution to account for variability and uncertainty in the data.

The third and fourth general statements acknowledge the paucity of data upon which to build claimant-favorable defaults and provide some historical background on the underlying reasons. The fifth statement is in relation to SC&A's concerns regarding the adequacy and completeness of the DOE mass balance reports for assigning bounding contaminant levels for use in dose reconstruction. This statement amounts to an assertion that the mass balance reports are credible and sufficient for conservative bounding. SC&A's concerns regarding this issue are summarized in the discussion supporting Finding #4 from SC&A (2011b). The remainder of this section consists of a table outlining the history of RU from 1944 to 1966, and appears to have been drawn from the DOE mass balance reports.

3.3 Specific Discussion and Responses to the SC&A Report

3.3.1 Primary Issue – Viability of the DOE Mass Balance Reports

This section begins with the following statement (NIOSH 2011, p. 5):

> *The primary issue deals specifically with the challenge to the DOE 2000 Mass Balance studies and reports as viable information sufficient to provide for DR for the purposes of the EEOICPA* [DOE 2000a-e]. ***The unstated implications are that the requirements for data integrity and accuracy should be held to a higher level of detail and accuracy than necessary for routine protection programs.*** [Emphasis added.]

SC&A believes that this statement by NIOSH misrepresents our position, which is that the mass balance reports were not intended to provide a basis for dose reconstruction. While we believe that the reports and associated data represent an extraordinary effort on the part of DOE and are adequate for a mass balance study, the data are highly variable and uncertain; SC&A believes

that the variability and uncertainty must be taken into account if the data are to be used as the basis for RU defaults.

NIOSH provided responses to this primary issue on three levels: basic effort and product; previous reports and resources; and industry limits and guides. Each of those topical responses is addressed below:

Basic Effort and Product

This section of NIOSH (2011) provides an overview of the organization and effort put forth by DOE in assembling the mass balance reports. It concludes with the following assertion as to the credibility of the reports:

> *The DOE 2000 Mass Balance Reports* [DOE 2000a-e] *are credible and sufficient for the purposes for which they are proposed – to establish a conservative bounding for all classes of workers. Do they provide all the detail and availability of "raw" data for independent statistical manipulation expected? No – There is a tacit requirement to trust the professional integrity and capabilities of the work group assembled for the purpose. Even if the "raw" data were available, it would require the services of the work group members or equivalent experienced professionals to make sense of it and derive the presentation already provided.*

SC&A is in agreement with NIOSH that the team of process knowledge experts assembled to produce the DOE mass balance reports probably comprised the most knowledgeable persons on the subject, and that reconstituting that group or any other to build on the foundation set by these reports is probably not feasible. However, SC&A believes that if the DOE reports (principally DOE 2000b) are to be used as the basis for bounding values in the dose reconstruction or SEC contexts, **there must be an accounting of the high variability in the available data and the associated uncertainties**. The reader is referred to pages 38–44 of SC&A (2011b) for a detailed analysis of the DOE documents and their applicability to dose reconstruction. That section was prepared by an SC&A Associate who was formerly employed by the DOE Office of Environmental Management (EM) and who was involved in managing the preparation of DOE (2000b).

A summary quote from SC&A 2011b (p. 41) follows:

> *Nonetheless, despite the extraordinary accomplishment of preparing* [DOE 2000b] *under such challenging circumstances, it cannot serve as a reliable source of information for precise or accurate data on TRU and fission product contaminant concentrations in recycled uranium that is reliably representative of the RU shipments to Fernald, Weldon Spring and other sites. It may or may not be possible to compile more complete and representative data, but the analysts who compiled* [DOE 2000b] *knew at the time that to obtain and analyze the full range of data needed to ensure a reasonably complete and representative*

> *characterization of the contaminant concentrations would require more time than was available in late 1999–early 2000.*

Previous Reports and Resources

This section of NIOSH (2011) lists five references to RU activities that took place in the DOE complex from about 1965 up to the mid-1980s. NIOSH concludes this section with the following statement (NIOSH 2011, page 8):

> *These previous studies, recommendations, conclusions, etc. were available to the DOE 1999–2000 Mass Balance Study work groups, which was itself a follow on to those studies with the added mission of addressing current political concerns discussed in the SC&A paper.*

SC&A is aware of the listed documents and, in fact, utilized them extensively in the preparation of SC&A (2011b). Probably the most insightful of these is *Report of the Joint Task Force on Uranium Recycle Materials Processing* (DOE 1985).

Industry Limits and Guides

This section provides a brief listing of several references from NIOSH (2008) that were used to support the NIOSH assertion that Pu concentrations in RU receipts at Fernald were controlled to 10 ppb U or less up until the early 1970s, when more highly contaminated tower and incinerator ashes were received. NIOSH acknowledges that, prior to 1986, the radiation protection and industrial hygiene programs at Fernald were probably not adequate to control exposures to these more highly contaminated sources.

Pages 27–29 of SC&A (2011b) provide an in-depth discussion of why we believe that the 10 ppb U level for Pu cited by NIOSH may not have bounded the RU materials shipped to Fernald prior to 1973. Several quotes from DOE (1985) are central to our position. The following is a summary statement from that report:

> *The FMPC has not been required by DOE to maintain accountability records of transuranic and fission product elements in the quantities generally received by the FMPC. As such, the Task Force could not determine, with confidence, the quantity of contaminants that may have been received and processed at the FMPC. Only best estimates were available for the review.* (DOE 1985, p. xi)

The section concludes with a discussion of Finding 5 from SC&A (2009) and Finding 9 from SC&A (2011b) (replicated below). Finding 5 is concerned with a potential source of RU that was not identified in the DOE mass balance reports. Finding 9 is in regard to a set of Hanford UNH data from 1971 that show a large number of samples far above 10 ppb U.

> ***Finding 5 (SC&A 2009):*** *NIOSH has not taken into account the RU originating in the Hanford U Plant during the period of uranium recovery from high-level waste. This RU may have characteristics in regard to trace radionuclides,*

> *including fission products that are very different from the ratios that NIOSH proposes to use. The validity of the ratios in the NIOSH paper for RU originating in the U Plant (directly or via some other DOE facility) has not been established.*

SC&A notes that additional research has indicated that the RU originating in the Hanford U Plant was most likely sent to the GDPs and not to Fernald. This finding was resolved at the April 19, 2011, Work Group meeting.

Finding #9 (SC&A 2011b): *The Hanford UNH data from the early 1970s suggest that the working specification for Pu was exceeded on a frequent basis with some batches much higher than the NIOSH default.*

NIOSH (2011) makes the following statement in reference to Finding #9:

> *Also, please note that it is clearly stated that UNH that did not meet the specs were sent back to the extraction plant for another extraction cycle.*
>
> *Thus the examples of analyses of UNH product streams that were reported above the limits seems* [sic] *expected and trivial – and the implications that the materials were released to the UO_3 plant unfounded. The product was either returned to the extraction process or blended down with a lower product. The PUREX process produced the better product from a contaminant standpoint and finished the recovery of stored uranium by 1958 (1952–1958).*

Note that SC&A did not imply that the out-of-specification UNH was sent to Fernald. Rather, we raised concerns that there are no data either confirming or refuting possible shipments of out-of-specification batches. The following statement is from page 62 of SC&A (2011b):

> *While it is recognized that this material could have been down-blended at later steps in production, it remains unclear whether batches of UO_3 in excess of the NIOSH default were shipped to Fernald and if so, whether Fernald personnel were aware of it and took precautionary measures.*

3.3.2 Second Major Issue – Specific RU Contaminant Defaults

This section begins with a 3-page (pp. 11–13) list of findings from SC&A (2009) and SC&A (2011b) related to the default values in NIOSH (2008). The NIOSH response begins on page 14; selected passages are replicated below:

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> *The previous NIOSH defaults were chosen very simplistically by choosing the highest values from the 19 process streams from the* [DOE 2000b] *boot strap mean values, and excluding the high values represented by the process stream directly from the GDP tower ash and decontamination residues, i.e. sub group number 10A. This stream was recorded as a recognized high hazard and handled*

accordingly and did not represent a continuous process or one with which any given worker would be exposed for an extended time period.

The SC&A report represents a major effort and produced information not previously examined, which indicates the need to reconsider the defaults. ***Upon further analyses we agree that though there is much data spread, lognormal distributions best describe the data sets. In response, the data presented in Reference 5, Appendices C. Attachment 1, Attachment E.2, Attachment F, and Attachment F.1 have been re-examined and lognormal distributions used with a 95th percentile value calculated for all operational process sub-groups.*** [Emphasis added]

Pages 14–15

Clearly the defaults are intended to represent the exposure potentials for the time period 1973 to the termination of processing and cleanup. The time period of 1961 (beginning of insertion of RU into the Fernald processes) to 1973 is a period represented by quite a different set of circumstances. *First all the generator sites (Hanford, SRS, and a small amount from West Valley) used the PUREX process (in addition to REDOX for a time at Hanford), which demonstrated the ability to provide UO_3 at <5 ppb at Hanford, <3 ppb at SRS and <10 ppb Pu at West Valley – with some additional contaminants identified from higher burn up commercial fuels.* [Emphasis added]

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The bulk of the data in the [DOE 2000b] *report at Fernald was taken during the 1970s and '80s when the RU contaminant levels increased dramatically.* ***The contaminant levels were as high as 4 ppm for Pu, which were reduced through immediate blending prior to introduction into the processes and resulted in the analyses of the 19 process subgroups reducing by a factor of 10 to a conservative value of 400 ppb, which included the concentration mechanisms within specific processes.*** *Since the care associated with handling of the RU materials in the early decade were less, the factor of 10 probably should not be applied to the maximum levels documented from the primary generating sites.* [Emphasis added]

The old and new NIOSH default RU contaminant concentrations, and the bases for the new values as understood by SC&A, are summarized in Tables 1 and 2. A discussion of the new values and their bases follows.

Table 1. Summary of Proposed NIOSH RU Default Values (1973–1989)

Radionuclide	NIOSH (2008)	NIOSH (2011)	Basis (DOE 2000b)
Pu-239	100 ppb U	400 ppb U	Subgroup 8; MgF_2
Np-237	3,500 ppb U	11,000 ppb U	Subgroup 11; Waste Residues
Tc-99	9,000 ppb U	20,000 ppb U	Subgroup 6B; LEU* products

*low enriched uranium

Table 2. Summary of Proposed NIOSH RU Default Values (1961–1973)

Radionuclide	NIOSH (2008)	NIOSH (2011)	Basis
Pu-239	100 ppb U	7 ppb U	PUREX
Np-237	3,500 ppb U	2 ppb U	Not provided
Tc-99	9,000 ppb U	19 ppb U	Not provided

To put the dosimetric significance of the default values in perspective, the reader is referred to SC&A (2011b), pp. 19–20. Organ dose ratios of the RU contaminants relative to uranium (U-234) were calculated using ICRP-68 dose coefficients and the default RU values in Table 1, column 2 (NIOSH 2008). By far, Pu-239 is the most significant, with 50-year equivalent doses to the liver and bone surfaces exceeding U-234 doses by factors of about 5 and 3, respectively (Classes M and S). The Np-237 ratio was slightly less than 1 for bone surfaces, and the highest ratio for Tc-99 was about 0.004 for stomach (Class M).

Bases for New Defaults

On pages 15 (see Section 3.3.2) and 17 of their response, NIOSH provides apparently inconsistent explanations for the selection of a new Pu default concentration for 1973–1989:

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> *The present choice of defaults is equally simplistic by choosing a default that was slightly higher than the highest process stream calculated at the 95th percentile of a lognormal distribution. The current choice of defaults should address the issues discussed in the SC&A findings above.*

This explanation for the defaults for 1973–1989 described on page 15 of NIOSH 2011 is problematic. In this explanation, NIOSH takes a high value from Subgroup 10A (tower ash residues), though not the highest,[1] and simply reduces it by a factor of 10, apparently to account for down-blending of the out-of-specification plutonium feed stocks. Note that these materials were historically referred to as Plutonium Out Of Specification (POOS) materials. SC&A believes this approach is without merit, because, (1) NIOSH has specifically excluded the Subgroup 10A data from their analysis, because they believe that these POOS materials are not representative of routine worker exposures, and (2) there is no technical basis for the selection of a factor of 10 for down-blending efficiency. In fact, Subgroup 10B from DOE (2000b), which represents UO_3 actually produced at Fernald from the POOS tower ash residues, is represented by 146 data points, with Pu concentrations ranging from 2 to 50 ppb U with an average of 20 ppb U. Given that the highest measured Pu concentration in tower ash was 7,757 ppb U, an upper bound down-blending factor of about 385 would apply.

The explanation for the defaults for 1973–1989 described on page 17 implies that they are based on the highest 95th percentile of lognormal fits to constituent levels for each of the 19 subgroup process datasets, excluding Subgroup 10A. This is the explanation provided by NIOSH at the April 19, 2011, Work Group meeting. The process subgroups from which the new NIOSH

[1] The highest Pu concentration in the tower ash shipments was in a 1980 shipment from the Paducah GDP. That value was 7,757 ppb U from Hopper T058. (NLO 1985)

defaults were derived for 1973–1989 are provided in column 4 of Table 1; for the 1961–1973 period, the only basis provided by NIOSH is the brief paragraph on PUREX output, as previously noted.

New Defaults and Timeline for Exposures

It is clear that the new defaults proposed in NIOSH (2011) are predicated on the assumption that the highly contaminated incinerator and tower ash receipts from the GDPs in the 1970s and 1980s resulted in elevated exposure potential for all workers throughout the Fernald complex, and that prior to those receipts, concentrations were limited to levels at or below those presumed to have existed in the feed materials (Table 2). Common to both periods is the assumption that feedstock contaminant levels adequately characterize worker exposures. That is, concentrating mechanisms are not thought to result in higher exposure potential for some groups of workers. SC&A has investigated these assumptions and found them to be highly questionable.

Discussions with a NIOSH Division of Compensation Analysis and Support (DCAS) subject matter expert at the April 19, 2011, Work Group meeting (ABRWH 2011, pp. 21–23) indicated that initial POOS repackaging took place in Plants 1 and 4; milling and down-blending took place primarily in Plant 1, as well as in other locations, but was upstream of refining and subsequent processes. Hinnefeld (1988, p. 5) indicates that the UO_3 produced from the POOS feedstock averaged about 40 ppb U (four times the specification) and was further down-blended before going to Plant 4 to be converted to uranium tetrafluoride (UF_4). NLO (1985) indicates that down-blending also took place in the rotary kiln in Plant 8, and that some of the UO_3 was converted to UF_4 in Plant 4 and down-blended with uncontaminated UF_4 before being reduced to metal in Plant 5. As previously noted, the Subgroup 10B materials have very low Pu concentrations in comparison to the Subgroup 10A feed stocks. This indicates that down-blending efforts were by and large successful. Thus, constituent levels in UF_4 to be reduced into metal, whether it originated from POOS feed stocks or some other source, would be expected to have been consistent, and likely fairly low.

As discussed in detail in SC&A (2011) and in our presentation to the Advisory Board at the meeting in St. Louis, Missouri, on May 24, 2011, magnesium fluoride (MgF_2) was known to concentrate transuranics and fission products, and was reused in crucible and reduction vessel liners for metal reduction throughout the production period of the plant. In addition, Plant 5 (metals production plant) air dust concentrations were known to have been high (DOE 2000b, Table D.1-15). Pages 51 to 53 of SC&A (2011b) detail the concentrating processes in MgF_2 that would give rise to much higher contaminant concentrations in Plant 5 than would be present in feedstock, and explains why **Plant 5 production workers, and also Plant 1 Millwrights who reprocessed the MgF_2 for reuse, were probably the most highly continuously exposed group of process workers, in terms of both dust loading and RU concentration throughout the entire period of RU processing.** This topic was discussed at length in the April 19 Work Group meeting (ABRWH 2011).

SC&A notes that the 95th percentile of the lognormal fit to the MgF_2 Pu data in DOE (2000b) is close to 400 ppb U and is based on a robust dataset of about 400 measurements taken at Fernald, which are well characterized by the lognormal distribution. The statistical parameters for that

dataset are found on pages 1143 to 1144 of DOE (2000b). A log-normal probability plot on page 1184 of DOE (2000b) demonstrates that the log fit actually over predicts at the 95th percentile.

The 95th percentile of the lognormal fit to the Np-237 data (Subgroup 11; waste residues) in DOE (2000b) is close to 11,000 ppb U and is based on a set of 94 measurements, which are well characterized by the lognormal distribution. The statistical parameters for that dataset are found on page 1144 of DOE (2000b). A log-normal probability plot on page 1197 of DOE (2000b) demonstrates that the log fit actually over predicts at the 95th percentile. Note that only subgroup 10A has a higher 95th percentile for Np-237, at about 17,300 ppb U.

The 95th percentile of the lognormal fit to the Tc-99 data (Subgroup 6B; low enriched uranium products) in DOE (2000b) is close to 60,000 ppb U and is based on a set of 178 measurements, which are overestimated by the lognormal distribution. The statistical parameters for that data set are found on page 1144 of DOE (2000b). A log-normal probability plot on page 1169 of DOE (2000b) demonstrates that the log fit over predicts the 95th percentile. However, based on the probability plot in DOE (2000b), it is not clear to SC&A how NIOSH derived a 95th percentile of 20,000 ppb U for Tc-99. Note, however, that Tc-99 has the least internal dose impact of the three RU contaminants.

SC&A believes that the 95th percentile of the MgF_2 dataset (400 ppb U) is a credible bounding default Pu concentration representative of the most highly continuously exposed group of Fernald process workers (Plant 5 metal workers and Plant 1 millwrights).[2] We also believe that the new higher defaults for Np-237 and Tc-99, though taken from different process streams, are credible bounds for these workers.

In determining a timeline for exposures, it is critically important to understand that, because POOS materials were down-blended principally at the 'front end' before being reduced to metal, the elevated concentrations measured in MgF_2 were independent of the feedstock concentrations and likely posed an elevated source of continuous exposure to Plant 5 workers throughout the period of RU processing. Thus, there is no technical basis for a lower set of default RU contaminant concentrations prior to 1973.

Adequacy of New Defaults for Down-blenders and Bystanders

Because the MgF_2 data may not bound potential exposures to POOS down-blenders and other nearby workers who were also potentially exposed to unblended POOS (referred to herein as bystanders), SC&A questions NIOSH's exclusion of the Subgroup 10A data in the derivation of new defaults. While we believe that it is reasonable to assume that POOS handling and down-blending was intermittent and would, therefore, be unlikely to pose a source of chronic exposure, we were unable to locate confirmatory data to that effect. Also, the inadequate radiation protection program under NLO's tenure casts serious doubt on NIOSH's contention that POOS worker exposures were carefully controlled in the pre-1986 environment. An excerpt from page 51 of SC&A 2011b summarizes our concern:

[2] This statement does not include potential exposure to millwrights from unblended POOS materials in Plant 1.

> *SC&A finds the assertion that contamination and worker exposures were carefully controlled during all periods of POOS processing to be questionable, as discussed in detail in Section 4.2 of this report. As noted in that section, DOE 1985 states that some of the workers handling the tower ash material were 'requested' (not required) to wear half-mask respirators, but it is uncertain whether this action was actually carried out and how many potentially exposed workers were covered. Also, radiation safety procedures to help control exposures from POOS material were not actually instituted until 1986.*

The Subgroup 10A data contain the highest Pu and Np-237 concentrations of the 19 subgroups and were discussed at the April 19, 2011, Work Group meeting (ABRWH 2011). SC&A notes that this dataset consists of only 39 points for Pu and Np, and that samples taken from the same hoppers and assayed independently for Pu (at Paducah and at Fernald) show large amounts of variability. Hopper 449, received from Paducah in 1980, is illustrative. Paducah reported a Pu concentration (sample basis) of 940 ppb for Hopper 449, while Fernald measured 2,789 ppb (sample basis). The corresponding Fernald measurement on a uranium mass basis was 7,005 ppb U (DOE 2000b, p. 663; NLO 1985, p. 28). The statistical parameters for Subgroup 10A are found on page 1144 of DOE (2000b). A log-normal probability plot on page 1190 of DOE (2000b) demonstrates that the log-normal fit is appropriate for this dataset. The 95th percentile for Pu from the probability plot appears to be about 3,000 ppb U; NIOSH (2011) cites a value of 1,732 ppb U. As of the April 19 Work Group meeting, NIOSH had not quantified or estimated the impact of excluding the Subgroup 10A data. **Thus, the question of whether the 400 ppb default for Pu based on the MgF_2 dataset and the 11,000 ppb U for Np-237, based on waste residues are bounding for the POOS handlers, down-blenders, and bystanders, remains open.**

Summary Conclusions – New RU Contaminant Defaults

In summary, the new proposed higher defaults in NIOSH (2011) and the subsequent discussion at the April 19, 2011, Work Group meeting represent the first instances in which NIOSH and SC&A have reached consensus on the central issue of bounding default values for RU at Fernald. Specifically:

- NIOSH has acknowledged the limitations and uncertainties in the data from the DOE reports upon which the NIOSH default values are based
- NIOSH has acknowledged that the arithmetic mean concentrations for the 19 subgroup processes in DOE (2000b) are not bounding, due to a high degree of variability and uncertainty
- NIOSH recognizes that chemical processes resulted in concentration of RU constituents above levels in feed materials (e.g., MgF_2 'dolomite' problem) and has proposed a set of new defaults that take this into consideration.

Based on the foregoing discussion SC&A believes that:

- The lower default values proposed by NIOSH in Table 2 for 1961–1973 are not bounding for any group of workers for any period of time.
- The new higher defaults in Table 1 are probably bounding for all workers during the period of RU production extending up to 1973.
- From 1973 until 1986, POOS down-blenders, handlers, and bystanders may have been exposed to higher concentrations of RU contaminants. The question of whether the proposed higher defaults in Table 1 are bounding for these down-blenders and associated bystanders remains open.
- In 1986, a robust radiation protection program was implemented. SC&A believes that the program adequately controlled potential RU exposures from 1986 to 1989.

3.3.3 Third Basic Issue – Fernald Radiation Safety Program Deficiencies

This section begins with a restatement of Finding #1 from SC&A (2011b) "**Questionable basis for NIOSH presumptions regarding the integrity of Fernald radiation safety programs prior to 1986.**" SC&A's concerns regarding NLO radiation safety program deficiencies are addressed in detail in Section 4.2 of SC&A (2011b), as excerpted above on page 18. As discussed above, the greatest impact of these deficiencies is on bounding intakes for down-blenders and bystanders from 1973–1986. NIOSH's response is found on page 18 of NIOSH (2011). The following excerpt from page 18 acknowledges SC&A's concerns regarding the adequacy of the worker protections in place prior to 1986:

> *As previously discussed it seems there was an apparent lack of timely and comprehensive response to the findings of the levels of RU contaminants and the personnel dosimetry issues following the 1985 period (and possibly the 1973 period) of increased contaminants from the GDP.*

SC&A notes that the author likely meant prior to 1980, as that was the year in which the most highly contaminated tower ash residues were received at Fernald. NIOSH goes on to justify the choice of a one-size-fits-all model. SC&A agrees that a single set of bounding defaults may be the best approach to reconstructing doses to RU at Fernald, since there is a paucity of data regarding worker locations at times during employment. Our concern, which has been repeated in this document and in previous communications with NIOSH, is that the credibility of such a model is entirely dependent on the selection of truly bounding yet plausible defaults. While we believe that the new higher defaults proposed by NIOSH are probably bounding for continuously exposed workers, the question of whether they are bounding for POOS handlers, down-blenders, and associated bystanders remains open.

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