Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

REVIEW OF ORAUT-RPRT-0055: *A COMPARISON OF EXOTIC TRIVALENT RADIONUCLIDE COWORKER MODELS AT THE SAVANNAH RIVER SITE*

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ABBREVIATIONS AND ACRONYMS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
ALARA	as low as reasonably achievable
Am	americium
AMW	all monitored workers
ANSI	American National Standards Institute
Bq	Becquerel
CATI	Computer Assisted Telephone Interview
Cf	californium
Cm	curium
COV	coefficient of variation
CTW	construction trades worker
d	day
DL	detection limit
dpm/L	disintegrations per minute per liter
dpm	disintegrations per minute
DOE	(U.S.) Department of Energy
DTPA	Diethylene Triamine Penta-Acetic
GM	geometric mean
GSD	geometric standard deviation
h	hour
ICRP	International Commission on Radiological Protection
L	liter
mBq	megabecquerel
MC	monitoring quantity
MDA	minimum detectable activity
mrem	millirem
mSv	milliseivert
nCi	Nanocurie
NCRP	National Council on Radiation Protection and Measurements
NCW	non-construction trades worker

NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH/OCAS Claims Tracking System
NRPB	National Radiological Protection Board
OMINEX	Optimization of Monitoring for Internal Exposures
OPOS	one person-one sample
ORAUT	Oak Ridge Associated Universities Team
Pu	plutonium
ROS	regression on order statistics
RPRT	report
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRS	Savannah River Site
Unk	unknown (job classification)

1.0 INTRODUCTION AND EXECUTIVE SUMMARY

The proposed methods for reconstructing unmonitored exposure to the trivalent actinides Am-241, Cm-244, and Cf-252 are described in RPRT-0055: *A Comparison of Exotic Trivalent Radionuclide Coworker Models at the Savannah River Site* (ORAUT 2012a). The proposed coworker model utilizes trivalent actinide urinalysis results that have been transcribed from hardcopy bioassay logbooks. The data were analyzed in accordance with the one person-one sample (OPOS) methodology outlined in RPRT-0053 (ORAUT 2012b). In addition, two distinct job classifications [construction trades worker (CTW) versus non-construction trades worker (NCW)] were compared to determine whether coworker stratification was warranted. The main conclusion of RPRT-0055 is that there is not a practically significant difference in the magnitude of available bioassay data for the two strata and so a single "all worker" coworker model was appropriate. Chronic intake rates were calculated utilizing all available worker data, which resulted in a single chronic intake rate from the start of the Special Exposure Cohort (SEC) period through 1994 (ORAUT 2013).

During the April 29, 2014, meeting of the Advisory Board on Radiation and Worker Health, SC&A was tasked with reviewing RPRT-0055 and associated documentation with a focus on the feasibility of reconstructing unmonitored exposures to trivalent actinides using the available coworker monitoring data. It should be noted that prior to this review, SC&A had performed reviews of RPRT-0053 (ORAUT 2012b) and the Savannah River Site (SRS) SEC Evaluation Report Addendum 3 (DCAS 2012). The former outlines the methodology for calculating the OPOS statistic, as well as comparing strata to determine if there are appreciable differences in the exposure potential for different job classifications. The latter report utilized the trivalent actinide database in order to reconstruct unmonitored thorium exposures. Many of the findings from those two reviews are therefore germane to the review of RPRT-0055 and so are replicated in this report.

The main body of this report is separated into seven main sections (Sections 2-8):

- Section 2: Evaluation of the Comparison of CTW and NCW Distributions
- Section 3: Additional Findings Related to the Use of OPOS and Maximum Possible Mean Methodology
- Section 4: Measurement Variation Among Aliquots of the Same Sample
- Section 5: Analysis of CTW Replicates
- Section 6: Effect of the Variation of Replicates and Uncertainties on Committed Equivalent Doses to the Bone Surface and Committed Effective Doses
- Section 7: Comparison of CTW Intakes with AMW Coworker Model
- Section 8: Evaluation of the Completeness of the Trivalent Bioassay Database

During the course of this review, SC&A identified 18 main findings and 7 observations as follows:

Finding 1 (formerly Finding 5 of SC&A 2013): SC&A has concluded that NIOSH's method for comparing the measurements of two sets of workers requires that the monitoring protocols of the two sets of workers were the same. NIOSH has stated that the protocol for CTW bioassays was different. As a result, the method used by NIOSH to compare CTW and NCW Am/Cm/Cf data does not meet the requirements for a valid comparison of the two bioassay datasets for the 1972–1989 period.

Finding 2 (formerly Finding 6 of SC&A 2013): NIOSH's coworker model for thorium [and Am/Cm/Cf] is based on its conclusion that CTW and NCW bioassay samples are drawn from the same distribution. A corollary of Finding [1] above is that NIOSH's coworker model, which combines NCW and CTW data, is based on an invalid comparison, and therefore is not suitable for estimating CTW thorium [and Am/Cm/Cf] doses for the 1972–1989 period.

Finding 3 (formerly Finding 7 of SC&A 2013): The SRS emphasis on incident-related monitoring of CTWs at SRS does not necessarily reflect differences between CTW work and NCW work. As a result, the emphasis on incident-related monitoring may have missed routine exposures for at least some CTW job types.

Finding 4 (formerly Finding 8 of SC&A 2013): The number of CTW data points is less than 30 in each aggregated period during 1984–1989. This is less than the minimum number required for a valid comparison between CTWs and NCWs. Therefore, NIOSH's conclusion that CTW and NCW sample distributions are the same is not valid for this period. As a result, the coworker model based on this conclusion has not been shown to be valid for this period.

Finding 5 (formerly Finding 9 of SC&A 2013): While NIOSH has not provided disaggregated data for 1981 and 1982, the number of CTW data points for 1982 is less than 30. Hence, the data for 1982 are also insufficient for a CTW-NCW distribution comparison.

Finding 6 (formerly Finding 11 of SC&A 2013): NIOSH has not demonstrated that the number of CTW samples is sufficient to simultaneously maintain low levels of Type 1 and Type 2 errors (for instance, less than 5% for Type 1 errors and less than 15% for Type 2 errors), even in the years when CTWs have more than 30 samples. SC&A's analysis indicates that when the geometric standard deviation (GSD) is much larger than the ratio of CTW to NCW geometric means (GMs), the rate of Type 2 errors will tend to be high. Type 2 errors occur when the null hypothesis (distributions are the same) is incorrectly accepted.

Finding 7 (formerly Finding 10 of SC&A 2013): Aggregating data over more than 1 year without reference to underlying processes and other data is not justifiable. NIOSH should provide a technical rationale for treating 1981–1982 and 1987–1989 differently than other years. Aggregation over more than 1 year to increase the number of data points is not a suitable technical rationale. If no sound basis can be provided for aggregating data over more than 1 year, NIOSH should do annual aggregating for calculating OPOS values. This is important for evaluating NIOSH's conclusion that CTW and NCW data are drawn from the same distribution. Furthermore, aggregation over multiple years rather than a single year to estimate an OPOS value increases the risk that the result would represent a mix of thorium exposure and Am/Cm/Cf exposure, rendering it scientifically questionable.

Finding 8 (formerly Finding 13 of SC&A 2013): NIOSH's interpretation of the below MDA [or detection limit (DL)] results for OPOS calculations is an interpretation of data entry conventions that contains an element of arbitrariness. It is systematically claimant unfavorable when a large fraction of the results are well below the MDA. This finding applies to all cases where NIOSH proposes to use OPOS data as presently calculated for coworker models, including those whose data are reviewed in this report (Am, Cm, Cf and thorium), as well as others such as neptunium and fission products.

Finding 9 (formerly Finding 14 of SC&A 2013): NIOSH's approach to using data well below the MDA, including negative numbers and zeros to calculate OPOS values, can sometimes yield scientifically meaningless results such as negative OPOS values, implying negative intakes. The problem of negative OPOS results is especially prevalent in the 1983–1989 period.

Finding 10 (formerly Finding 15 of SC&A 2013): The present NIOSH method of calculating OPOS data would result in systematically very claimant-unfavorable results in the case of the Am, Cm, Cf dataset. This would be true of thorium dose estimates as well as Am, Cm, Cf dose estimates. This is because the vast majority of bioassay results for the 1972–1989 period are well below the MDA.

Finding 11 (formerly Finding 16 of SC&A 2013): SC&A is concerned that some reported results in the logbooks that are above the MDA are averages of results that are both well below and well above the MDA. This is much better than the NIOSH OPOS procedure when even below MDA results are used at face value, but it is still a concern since such practices vitiate the connection between the raw data and the workers' intake experience in the real world.

Finding 12 (formerly Finding 19 of SC&A 2013): Many reported OPOS values that are above the DL are actually the average of negative and positive normalized disc results, or are the average of results with large differences among the different discs derived from the same urine sample. Such average results no longer retain an unambiguous connection to the intake of the worker, do not represent excretion rates of workers, and therefore should not be used to calculate intake rates.

Finding 13 (formerly Finding 20 of SC&A 2013): Many reported OPOS results below the DL are the average of normalized disc results that have a large variation between them. This indicates that the resultant average of disc results is highly uncertain. Such average results do not have an unambiguous connection to the intake of workers, do not represent excretion rates, and should not be used to calculate intake rates.

Finding 14: Given the observed variation in the magnitude of multiple measured aliquots of the same sample, SC&A questions whether the dataset is sufficiently accurate and adequate for use in reconstructing doses to both monitored and unmonitored workers. NIOSH should examine and justify the dataset in the context of the large uncertainties associated with the observed measurement variability to justify its use in dose reconstruction.

Finding 15: NIOSH must demonstrate the usability of the bioassay reported results for trivalent actinides in terms of retrospective dose calculations for the individual claimants. Each claim

must be analyzed case-by-case, taking into consideration the organ or tissue for which the committed effective dose is calculated and its probability of causation.

Finding 16: NIOSH should review the number of bioassay samples that carry large discrepancies in disc activity concentrations, as well as the magnitude of variation in activity concentration in individual disc results, in order to establish the adequacy of the available records to derive the 50th, 84th and 95th percentile coworker's intakes for the trivalent actinides.

Finding 17: Uncertainties observed in the urine in-vitro methodology are very high for the sampled claimants, making accurate intake assessments particularly difficult. This is evident in multiple instances where differences in disc results for the same sample are significant. Additionally, the reported urinalysis activity was very low for one claimant who had a confirmed high intake based on fecal and in vivo measurements. This may be due to problems in the urine bioassay method.

Finding 18: The 95th percentile daily intake rates for Am-241 and Cm-244 in the period 1973–1994 predict excretion rates that are below the DL for the first 10 years of continuous exposure. Any worker that had a positive excretion rate during the first 10 years of exposure without an indication of a specific incident occurring in a small interval of time before the sampling will be misrepresented by the 95th percentile coworker model.

Observation 1: SC&A noted that many results were excluded from the OPOS analysis for various reasons including no apparent date to the sample, sample was marked lost in process, or chelation was involved. SC&A identified 52 samples that were excluded, mainly based on a missing date, which likely could still be used in the coworker model since the date of the report can be used to accurately place the sample in a given year.

Observation 2: Based on the job title analysis, it is apparent that the monitored worker population is not homogeneous but biased towards job types that are more likely to be exposed, such as lab technicians/technical assistants and operators.

Observation 3: The monitoring program is heavily focused on Building 773 (the Savannah River Laboratory) where research campaigns were conducted using trivalent actinides and the highest potential for intake would likely occur.

Observation 4: When comparing the coworker database and individual claimant records, neither source appears to be complete. However, the additional records found in the claimant files had less positive results than the additional records found in the coworker database. Therefore, one can conclude that the samples missing from the coworker database do not adversely affect the formulation of a coworker model.

Observation 5: Approximately 1.9% of the claimant samples reviewed showed discrepancies in the year of the sample. While this would be considered a "critical error" in the transcription of the data, it is very comparable to the critical error rate of 1% described by NIOSH in Section 3.1 of RPRT-0055.

Observation 6: SC&A observed 80 claimant samples that were taken during or in the subsequent months following chelation treatment. These samples should be removed from the coworker dataset.

Observation 7: SC&A noted that about 9% of the monitored claimants showed discrepancies between the job classifications displayed in the coworker database versus available NIOSH/OCAS Claims Tracking System (NOCTS) records. It would be beneficial to perform a detailed characterization of how job titles have been established in the coworker database. To the extent feasible, an adequate quality assurance activity should be undertaken to ensure that monitored workers are correctly placed in the CTW and NCW strata.

2.0 EVALUATION OF THE COMPARISON OF CTW AND NCW DISTRIBUTIONS

Attachment A to RPRT-0055 (ORAUT 2012a) includes regression on order statistics (ROS) and effective fit plots for all monitored workers (AMWs), CTWs, and workers not classified as CTWs (non-construction trades workers or NCWs) covering the years from 1966 to 1989. A fourth group was created that includes all NCWs and those workers with unknown job classifications (NCW+unks). Although effective fit plots are shown for all years, the analysis presented in RPRT-0055 is based largely on the ROS plots. The effective fit method was applied for CTWs and NCWs in the 1981–1982 period and for CTWs in 1984 and 1986.

This section provides a comparison of the probability distributions obtained from the ROS plots for the CTW and NCW strata. Each plot provides the parameters of a lognormal distribution obtained by applying the ROS procedure to the OPOS bioassay results for each worker in each stratum. There are a total of 19 plots for each stratum, covering time periods from 1 to 3 years, usually 1 year.

The total number of bioassay results, the number of OPOS results (N) and the number of positive OPOS results (n) for each period and stratum are shown in Table 1. The table also includes the CTW percentage of the total number of records in each category. Although there are a relatively large number of NCW records in each period, the number of CTW OPOS results is much smaller in all years and categories. The percentage of CTW records ranges from 6% to 35% depending on the category. Note that there are less than 30 CTW OPOS records in the period from 1984 through 1989. When using ROS, the fitted distribution is estimated using only the positive OPOS results. There are less than 30 positive CTW OPOS records for the ROS fit in over half of the periods analyzed (1966–1968, 1977, 1978 and 1980 through 1989).

The GM and GSD of the lognormal distributions of urinary excretion rates obtained using the ROS procedure are shown in Table 2 for each period and stratum. The table also includes the 95th percentile of the lognormal distributions and the ratio of the CTW estimates to the NCW estimates for each parameter. The year with the largest ratio of the CTW GM to the NCW GM is 1985. This year is the only year reported to have a statistically significant difference in the Peto-Prentice comparison between the CTW and NCW strata reported in RPRT-0055 (Table 4-1: Strata Comparisons). The same significant outcome occurs when CTWs are compared with the NCW+unk stratum.

Figure 1 shows a log-scale plot of the GSD versus the GM in the 19 time periods shown in Table 2. Except for the points at the upper left of the plot, the two strata appear to have similar lognormal distributions. These points account for the 4 very high values of the GSD ranging from approximately 19 to 67 in Table 2 for NCWs and CTWs in 1981–1982, and for CTWs in 1984 and 1986. As noted above, these are the four periods where the effective fit method was elected in RPRT-0055. The high GSDs in these four periods led to correspondingly high estimates for the 95th percentile of the ROS-fitted lognormal distributions. The 95th percentile of the 38 lognormal distributions shown in Table 2 are all less than 2.4 dpm/day, with the exception of the 1984 period for CTWs which required the effective fit procedure.

Table 1. Number of Bioassay Results, OPOS Results, and Positive OPOS Results

	Total Bioassay Results*		OPOS Results*		Positive OPOS Results*		CTW % of Total		Positive OPOS Results
			(N)		(n)		Total Results	OPOS Results	
Period	NCW	CTW	NCW	CTW	NCW	CTW		(N)	(n)
1966–1968	1071	240	329	101	15	8	18	23	35
1969	645	230	277	95	63	27	26	26	30
1970	1593	328	451	124	184	52	17	22	22
1971	1545	292	550	107	431	81	16	16	16
1972	1312	208	525	109	451	93	14	17	17
1973	969	243	509	115	231	56	20	18	20
1974	876	162	357	86	190	46	16	19	19
1975	628	173	356	94	161	48	22	21	23
1976	523	148	346	90	151	47	22	21	24
1977	368	87	292	68	86	16	19	19	16
1978	232	66	171	49	93	24	22	22	21
1979	337	79	234	67	131	37	19	22	22
1980	198	44	178	42	77	22	18	19	22
1981–1982	524	80	379	44	90	16	13	10	15
1983	255	41	232	39	59	17	14	14	22
1984	234	63	210	20	94	11	21	9	10
1985	266	42	214	24	93	18	14	10	16
1986	253	101	219	26	57	11	29	11	16
1987–1989	598	65	336	25	173	12	10	7	6

*Source: RPRT-0055, Table 3-1, Figures A-39 to A-57, and Figures A-72 to A-90.

Table 2. Geometric Mean (GM) and Geometric Standard Deviation (GSD), and 95th Percentile of Lognormal Distributions

	GM*		GSD*		95th Percentile		Ratio: CTW/NCW		
	(dpm/d)				(dpm/d)		GM	GSD	95th Percentile
Period	NCW	CTW	NCW	CTW	NCW	CTW			
1966–1968	2.7E-01	1.3E-01	2.93	5.63	1.59	2.32	0.5	1.9	1.5
1969	2.6E-01	5.6E-01	3.34	1.78	1.88	1.46	2.2	0.5	0.8
1970	2.1E-01	2.4E-01	2.65	1.64	1.02	0.53	1.2	0.6	0.5
1971	1.7E-01	1.7E-01	2.59	2.10	0.80	0.58	1.0	0.8	0.7
1972	7.1E-02	7.4E-02	3.34	2.78	0.51	0.39	1.0	0.8	0.8
1973	7.8E-03	9.5E-03	7.71	9.08	0.22	0.36	1.2	1.2	1.6
1974	8.7E-03	1.4E-02	11.66	5.97	0.49	0.26	1.6	0.5	0.5
1975	1.0E-02	9.3E-03	7.26	7.96	0.27	0.28	0.9	1.1	1.0
1976	1.2E-02	1.5E-02	6.63	5.25	0.27	0.23	1.3	0.8	0.9
1977	3.9E-03	2.8E-03	11.32	13.60	0.21	0.21	0.7	1.2	1.0
1978	2.8E-02	1.5E-02	10.64	9.12	1.38	0.57	0.5	0.9	0.4
1979	2.4E-02	2.6E-02	10.82	13.64	1.20	1.94	1.1	1.3	1.6
1980	9.4E-03	9.0E-03	7.20	10.88	0.24	0.46	1.0	1.5	1.9
1981–1982	1.3E-03	2.9E-03	18.81	52.91	0.16	2.00	2.3	2.8	12.7
1983	4.7E-03	1.2E-02	9.10	7.43	0.18	0.33	2.6	0.8	1.9
1984	7.3E-03	5.1E-03	9.15	67.47	0.28	5.24	0.7	7.4	18.8
1985	9.8E-03	5.1E-02	10.35	5.74	0.46	0.91	5.2	0.6	2.0
1986	4.2E-03	1.5E-03	9.00	61.68	0.15	1.32	0.4	6.9	8.5
1987–1989	1.8E-02	9.4E-03	6.11	10.87	0.35	0.48	0.5	1.8	1.4

*Source: RPRT-0055, Figures A-39 to A-57 and A-72 to A-90.

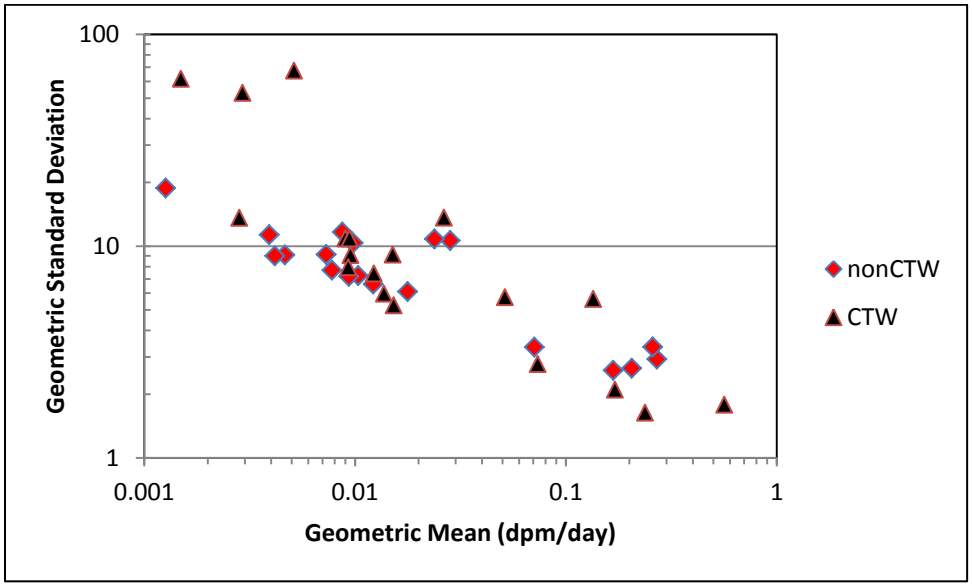


Figure 1. Scatter Plot of Geometric Mean (dpm/day) vs. Geometric Standard Deviation

The GMs for each group of workers in each time period are compared in Figure 2. If the CTW and NCW GMs were identical in every year, the plot would have perfect symmetry. Both strata have relatively high GMs from 1966 through 1972. In the years after 1972, the GMs are much smaller for both groups. There are apparent deviations from symmetry in three periods, 1966–1968, 1969, and 1985. In 1966–1968, the CTW GM is smaller than the NCW GM, with a ratio of 0.5. The year 1969 shows a relatively large difference, although the ratio of the CTW to NCW GMs in this period is only 2.2, as compared with the significantly high ratio of 5.2 for 1985.

Attachment A contains plots comparing the fitted lognormal distributions for the CTW and NCW strata in each time period. The GM of each distribution is shown as a vertical dotted line in these plots. In most periods, the plotted distributions and GMs are very similar and little evidence of a practical difference can be found between the two strata.

Figure 3 shows a comparison of the 95th percentiles of the lognormal distributions in each period. Although the GMs shown in Figure 2 for both groups were distinctly lower in the later years, the 95th percentiles do not show a similar reduction in the later years.

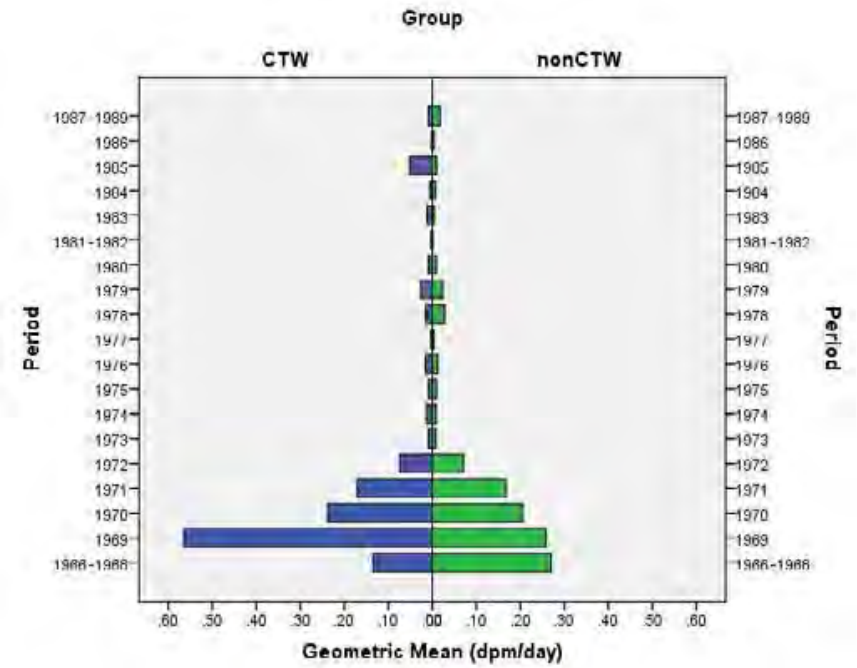


Figure 2. Comparison of NCW and CTW Geometric Means, 1966 to 1989

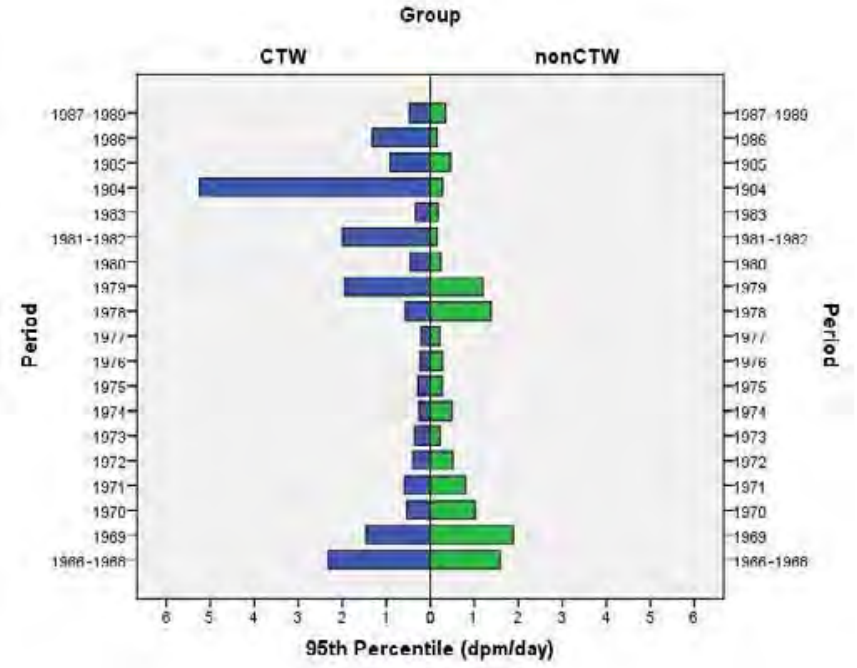


Figure 3. Comparison of NCW and CTW 95th Percentiles, 1966 to 1989

RPRT-0055 applies hypothesis testing to compare the CTW and NCW strata following the procedures described in RPRT-0053 (ORAUT 2012b). Table 4.1 in RPRT-0055 reports the results of the Peto-Prentice test comparing the CTW and NCW strata in each period. A similar set of Peto-Prentice test results are reported for a comparison of the CTW with the NCW+unk strata. The p-values for the two sets of tests are shown in Table 3. The p-values for testing of the CTW versus NCW are compared with the p-values for testing CTW versus NCW+unk in Figure 4. The plot is very symmetric, indicating that there is little difference if the CTW stratum is compared with the NCW or with the NCW+unk strata. For this reason, only the CTW versus NCW comparison is addressed in the preceding and following discussions. Significant test results have low p-values ($p<0.05$). A significant difference is observed in 1985, while borderline significance is attained in the 1981–1982 and 1983 periods. The period 1985, shown with dark shading in Table 3, is the only period reported to have a significant difference using the Holm multiple test procedure. Two lightly shaded periods, 1981–1982 and 1983, show significant differences on a single-test basis, but do not show a significant difference using the multiple testing procedure.

The p-values for the Peto-Prentice test reported in RPRT-0055 are for a two-sided test for inequality of the CTW and NCW strata. The two-sided test will report a significant difference if the CTWs significantly exceed the NCWs or if the NCWs significantly exceed the CTWs. A one-sided test for inequality will report a significant difference only when the CTW stratum significantly exceeds the NCW stratum. The normalized test score (z) for a one-sided test of inequality in each period is shown in Figure 5. Here, positive values of z denote periods when the CTW distribution exceeds the NCW, and negative values of z denote periods when the NCW distribution exceeds the CTW. If the absolute value of the normalized score exceeds 1.96 (i.e., outside of the region between the vertical dashed lines in the figure), there is a significant difference for that single test. The periods 1981–1982, 1983, and 1985 have scores high enough for a significant test result if individual years were to be tested. Of these three periods, the Holm cutoff for multiple 2-sided testing shows a significant difference only for 1985. The normal scores for these three time periods are all positive and greater than 2, indicating that the CTW distribution may exceed the NCW distribution. This information is not available when only the p-values for a two-sided test are reported in RPRT-0055.

The frequency distribution of normalized test scores for a one-sided Peto-Prentice test is shown in Figure 6. The distribution is approximately normal with a slight tendency toward the right with a mean of +0.23, indicating slightly higher values for the CTW stratum when all periods are considered. When the absolute value of the normalized score exceeds 1.96 (marked by the vertical dashed lines), there is a significant difference based on that single test. The excretion rates calculated for the coworker model are used to calculate intakes. The intakes are estimated over periods longer than 1 year. NIOSH applies a multiple hypothesis testing procedure designed to reach a single decision regarding difference between strata that applies over all years with available data, although this length of time may exceed the actual periods used for intake assessment. The multiple hypothesis test procedure should be applied to the same set of years used for intake modeling, thus allowing for differences between strata in some multiyear intake periods while not in others, rather than a single decision applied to all years with data. Treating the 1980s as a separate multiyear period may show significant differences between the two strata that otherwise would not be seen when the Holm procedure is applied to all years.

Table 3. Peto-Prentice Test p-Values from RPRT-0055

Period	CTW:NCW	CTW:NCW+unk
1966–1968	0.355	0.375
1969	0.177	0.179
1970	0.982	0.892
1971	0.806	0.813
1972	0.769	0.705
1973	0.331	0.338
1974	0.854	0.868
1975	0.577	0.547
1976	0.256	0.302
1977	0.359	0.450
1978	0.240	0.219
1979	0.930	0.908
1980	0.276	0.265
1981–1982	0.024	0.032
1983	0.013	0.007
1984	0.126	0.093
1985	0.001	0.001
1986	0.127	0.178
1987–1989	0.680	0.680

Source: RPRT-0055, Table 4-1

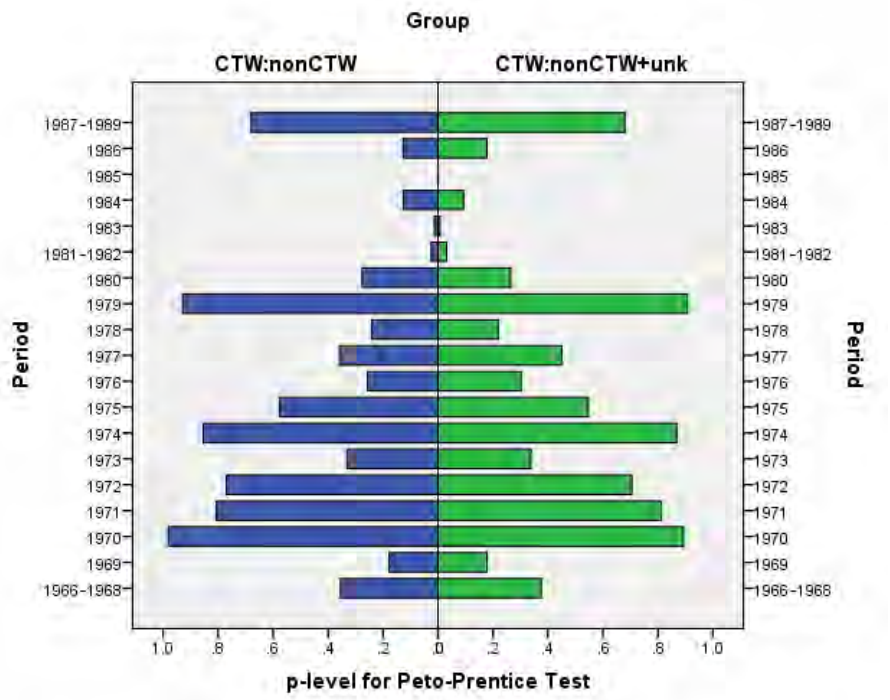


Figure 4. Comparison of Peto-Prentice p-Levels for Testing CTW vs. NCW and for Testing CTW vs. NCW+Unk

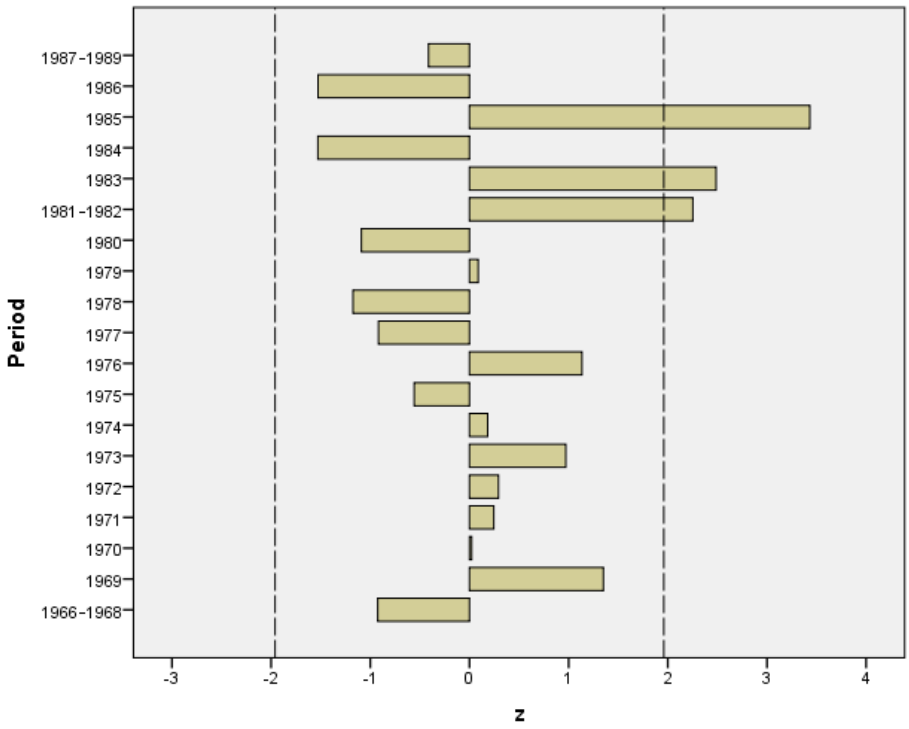


Figure 5. Normalized Test Scores over Time for 1-Sided Peto-Prentice Test

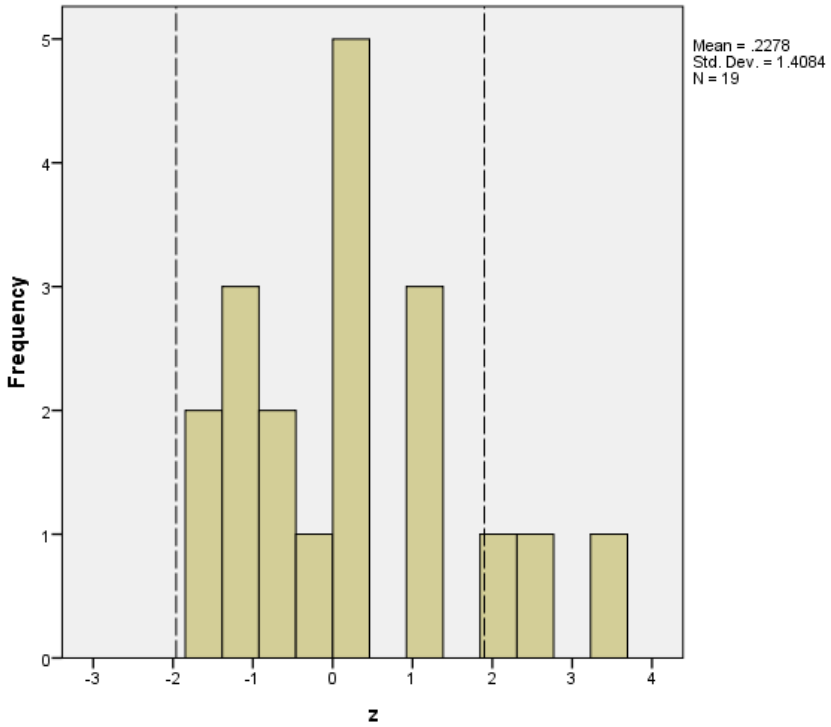


Figure 6. Frequency Distribution of Normalized Test Scores for 1-Sided Peto-Prentice Test

SC&A concludes that its findings related to sample size and the quality of the data presented in our review of thorium issues at SRS (SC&A 2013) also apply to RPRT-0055 with minor modifications (shown in italics). These findings were as follows:

Finding 1 (formerly Finding 5 of SC&A 2013): SC&A has concluded that NIOSH's method for comparing the measurements of two sets of workers requires that the monitoring protocols of the two sets of workers were the same. NIOSH has stated that the protocol for CTW bioassays was different. As a result, the method used by NIOSH to compare CTW and NCW Am/Cm/Cf data does not meet the requirements for a valid comparison of the two bioassay datasets for the 1972–1989 period.

Finding 2 (formerly Finding 6 of SC&A 2013): NIOSH's coworker model for thorium [and Am/Cm/Cf] is based on its conclusion that CTW and NCW bioassay samples are drawn from the same distribution. A corollary of Finding [1] above is that NIOSH's coworker model, which combines NCW and CTW data, is based on an invalid comparison, and therefore is not suitable for estimating CTW thorium [and Am/Cm/Cf] doses for the 1972–1989 period.

Finding 3 (formerly Finding 7 of SC&A 2013): The SRS emphasis on incident-related monitoring of CTWs at SRS does not necessarily reflect differences between CTW work and NCW work. As a result, the emphasis on incident-related monitoring may have missed routine exposures for at least some CTW job types.

Finding 4 (formerly Finding 8 of SC&A 2013): The number of CTW data points is less than 30 in each aggregated period during 1984–1989. This is less than the minimum number required for a valid comparison between CTWs and NCWs. Therefore, NIOSH's conclusion that CTW and NCW sample distributions are the same is not valid for this period. As a result, the coworker model based on this conclusion has not been shown to be valid for this period.

Finding 5 (formerly Finding 9 of SC&A 2013): While NIOSH has not provided disaggregated data for 1981 and 1982, the number of CTW data points for 1982 is less than 30. Hence, the data for 1982 are also insufficient for a CTW-NCW distribution comparison.

Finding 6 (formerly Finding 11 of SC&A 2013): NIOSH has not demonstrated that the number of CTW samples is sufficient to simultaneously maintain low levels of Type 1 and Type 2 errors (for instance, less than 5% for Type 1 errors and less than 15% for Type 2 errors), even in the years when CTWs have more than 30 samples. SC&A's analysis indicates that when the geometric standard deviation (GSD) is much larger than the ratio of CTW to NCW geometric means (GMs), the rate of Type 2 errors will tend to be high. Type 2 errors occur when the null hypothesis (distributions are the same) is incorrectly accepted.

3.0 ADDITIONAL FINDINGS RELATED TO THE USE OF OPOS AND THE MAXIMUM POSSIBLE MEAN METHODOLOGY

RPRT-0055 proposes to average raw worker data to yield an OPOS result for each worker in each time period. The comparisons of the distributions of the two groups of workers are made using OPOS results derived from the raw data. The period of averaging of raw data is usually, but not always, 1 year. As many as 3 years are used in some periods. Additional findings were presented in SC&A 2013 that address the use of OPOS in coworker modeling. The findings presented in the thorium review also apply to the use of OPOS for the exotic radionuclides. The OPOS-related findings were as follows:

Finding 7 (formerly Finding 10 of SC&A 2013): Aggregating data over more than 1 year without reference to underlying processes and other data is not justifiable. NIOSH should provide a technical rationale for treating 1981–1982 and 1987–1989 differently than other years. Aggregation over more than 1 year to increase the number of data points is not a suitable technical rationale. If no sound basis can be provided for aggregating data over more than 1 year, NIOSH should do annual aggregating for calculating OPOS values. This is important for evaluating NIOSH's conclusion that CTW and NCW data are drawn from the same distribution. Furthermore, aggregation over multiple years rather than a single year to estimate an OPOS value increases the risk that the result would represent a mix of thorium exposure and Am/Cm/Cf exposure, rendering it scientifically questionable.

Finding 8 (formerly Finding 13 of SC&A 2013): NIOSH's interpretation of the below MDA [or detection limit (DL)] results for OPOS calculations is an interpretation of data entry conventions that contains an element of arbitrariness. It is systematically claimant unfavorable when a large fraction of the results are well below the MDA. This finding applies to all cases where NIOSH proposes to use OPOS data as presently calculated for coworker models, including those whose data are reviewed in this report (Am, Cm, Cf and thorium), as well as others such as neptunium and fission products.

Finding 9 (formerly Finding 14 of SC&A 2013): NIOSH's approach to using data well below the MDA, including negative numbers and zeros to calculate OPOS values, can sometimes yield scientifically meaningless results such as negative OPOS values, implying negative intakes. The problem of negative OPOS results is especially prevalent in the 1983–1989 period.

Finding 10 (formerly Finding 15 of SC&A 2013): The present NIOSH method of calculating OPOS data would result in systematically very claimant-unfavorable results in the case of the Am, Cm, Cf dataset. This would be true of thorium dose estimates as well as Am, Cm, Cf dose estimates. This is because the vast majority of bioassay results for the 1972–1989 period are well below the MDA.

Finding 11 (formerly Finding 16 of SC&A 2013): SC&A is concerned that some reported results in the logbooks that are above the MDA are averages of results that are both well below and well above the MDA. This is much better than the NIOSH OPOS procedure when even below MDA results are used at face value, but it is still a concern since such practices vitiate the connection between the raw data and the workers' intake experience in the real world.

Finding 12 (formerly Finding 19 of SC&A 2013): Many reported OPOS values that are above the DL are actually the average of negative and positive normalized disc results, or are the average of results with large differences among the different discs derived from the same urine sample. Such average results no longer retain an unambiguous connection to the intake of the worker, do not represent excretion rates of workers, and therefore should not be used to calculate intake rates.

Finding 13 (formerly Finding 20 of SC&A 2013): Many reported OPOS results below the DL are the average of normalized disc results that have a large variation between them. This indicates that the resultant average of disc results is highly uncertain. Such average results do not have an unambiguous connection to the intake of workers, do not represent excretion rates, and should not be used to calculate intake rates.

4.0 MEASUREMENT VARIATION AMONG ALIQUOTS OF THE SAME SAMPLE

As noted in Findings 12 and 13, the calculated OPOS excretion rates not only represent the average of multiple samples over a given timeframe (1–3 years), but also the average of measurements within the same sample. An example of an Am/Cm/Cf bioassay logbook is shown below in Figure 7. Each line in the figure represents a single voiding which has been split into anywhere from 2 to 10 separate aliquots (single measurements were also observed for an individual sample). In this case, the sample was split into three aliquots. Only the right half of the bioassay logbook is shown in Figure 7, the left half would display other sample information such as worker name, volume of sample, payroll number, work area, bottling date, lab received date, and sample type (routine, special, follow-up, etc.).

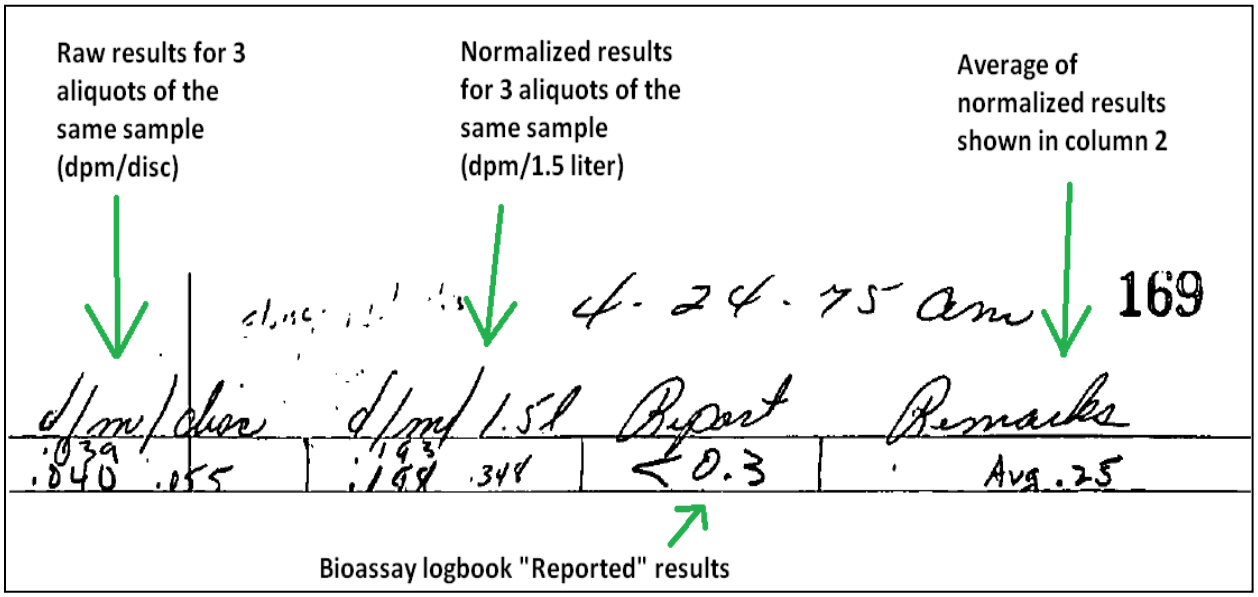


Figure 7. Example of a Trivalent Bioassay Logbook Entry

As seen in the figure, the raw count results for this sample are shown in column 1 (0.039, 0.04, and 0.055 dpm/disc), and the raw values are normalized to a daily excretion rate in column 2 (0.193, 0.198, and 0.348 dpm/1.5L). In this case, 2 of the 3 aliquots measured below the DL of 0.3 dpm/1.5L, and one measurement was positive (0.348 dpm/1.5L). For the purpose of calculating an OPOS value, the three normalized aliquot values are averaged, which results in a value of 0.246 dpm/1.5L. This comports with the note in the "Remarks" column of the bioassay log; however, it should be noted that the "Report" columns truncate this value at the DL (i.e., "<0.3").

SC&A expressed significant concerns on the variability in individual samples in its white paper, *SC&A Review of Addendum 3 to the NIOSH Savannah River Site Special Exposure Cohort (Sec-00103) Evaluation Report* (SC&A 2013, Section 4.2), and again during recent Work Group discussions (ABRWH 2014a, ABRWH 2014b). This is especially true when aliquot

measurements of the same urinalysis sample show values both above and below the MDA. To gain insight into the prevalence of the observed variability including positive measurements, SC&A specifically examined all urinalysis samples displaying at least one aliquot with a positive measurement. An overview of these observations is presented in Table 4. As seen in the table, only about 12% (1,055 in total) of all urinalysis samples contained at least one positive aliquot measurement. Of those 1,055 samples exhibiting a positive measurement, over 54% also displayed a negative aliquot measurement that was less than the MDA.

Table 4. Overview of Single Urinalysis Samples with at least One Positive Aliquot Measurement

Category	Total Number	Percent of All Samples	Percent of All Samples with Positive Measurements
Total # Individual Urinalysis Samples	8,483	–	–
# Urinalysis Samples with at Least One Positive Aliquot Measurements	1,055	12.4%	–
# Samples with Only Positive Aliquot Measurements	484	5.7%	45.9%
# of Samples with Mixed Positive and Less than MDA Aliquot Measurements	571	6.7%	54.1%

SC&A compared the relative difference between the maximum and minimum aliquot measurement for the 484 samples in which all measurements were positive by calculating the ratio (max/min) and differential (max-min) between the high and low results. This analysis is shown in Table 5. The table shows that the ratio for this group averaged just over a factor of 2 and could range as high as a factor of 230. The rank-ordered 95th percentile ratio was 2.76. The differential between the maximum and minimum aliquot in a given sample averaged over 5 dpm/1.5L (over a factor of 17 times the MDA). The GM of the observed differential was 0.54 dpm/1.5L, or nearly a factor of 2 times the MDA.

A similar analysis calculating the differential in the high and low aliquot was performed for the 571 urinalysis samples that had a mix of positive aliquots and below MDA aliquots. The calculated differential is shown in Table 6. The maximum and GM differentials were very similar to the "all positive" group, although the average and 95th percentile were much lower. Only the differential was considered for this group, because the ratios are severely complicated in instances of results showing very low, zero and negative results.

Table 5. Ratio and Differential between the Largest and Smallest Measured Aliquot among the 484 "All Positive" Samples

Category	Ratio [Max Aliquot/Min Aliquot (Unitless)]	Differential [Max Aliquot – Min Aliquot] (dpm/1.5L)
Maximum	231.36	478.6
Average	2.17	5.27
Geometric Mean	1.46	0.54
95th Percentile	2.76	17.15

Table 6. Differential between the Largest and Smallest Measure Aliquot among the 571 Samples Exhibiting both Positive and Less than MDA Measurements

Category	Differential [Max Aliquot – Min Aliquot] (dpm/1.5L)
Maximum	431.0
Average	1.75
Geometric Mean	0.49
95th Percentile	2.44

For specific worker examples showing significant variation among the same aliquot measurement, please refer to Section 4.2 of SC&A 2013.

Finding 14: Given the observed variation in the magnitude of multiple measured aliquots of the same sample, SC&A questions whether the dataset is sufficiently accurate and adequate for use in reconstructing doses to both monitored and unmonitored workers. NIOSH should examine and justify the dataset in the context of the large uncertainties associated with the observed measurement variability to justify its use in dose reconstruction.

Note: This general issue was discussed in the context of the thorium coworker models during the February 26, 2014, Work Group meeting. NIOSH agreed that further research, analysis and justification was [sic] *warranted on the issue of the variability of multiple measurements of the same urinalysis sample.* (ABRWH 2014b, pp. 193–198)

5.0 ANALYSIS OF CTW REPLICATES

In Section 7, SC&A examines a set of 13 CTW workers with positive bioassay samples to determine if these workers are bounded by the 95th percentile of the coworker model. A total of 31 bioassay samples were collected from these workers, and multiple aliquots of each sample were submitted for laboratory measurement. The results of the replicated measurements are summarized in Table 7. The number of replicates ranged from 2 to 9 over the 31 urine samples, with a total of 115 replicated measurements. The remaining columns show the mean (μ), standard deviation (σ), and coefficient of variation (COV=σ/μ) of the replicated measurements on each urine sample. These replicates provide an opportunity to examine the extent of measurement error during this period.

Figure 8 shows a series of box plots, one for each of the 31 urine samples. The range of replicate values for each sample is shown by the extent of the "whiskers" drawn above and below each box. Two outliers are denoted by small circles and identified by its replicate number. Table 7 shows the percentage COV of the 31 positive CTW bioassay samples. In Figure 9, the COV for each sample is expressed as a percentage of the mean of the replicated measurements for that sample. The COV values range from less than 7% for sample 24 (with a set of four replicates) to almost 70% for sample 19 (which has an identified outlier in Figure 8).

In many situations, the COV of replicate measurement as a percentage of the replicate mean will depend on the magnitude of the results, with smaller percentage variations at higher magnitudes. The scatter plot of the COV versus the logged mean for each sample shown in Figure 10 shows a weak association in this direction (R^2=0.12, t=-1.97). It is also likely the measurement techniques will improve over time with a corresponding reduction in the COV of replicate measurements. The scatter plot of COV versus time in Figure 11 shows scant evidence for improvement over the 10-year time span covered by this set of measurements (R^2=0.02, t=-0.77).

Table 7. Analysis of Replicated Measurements on 31 Urine Samples

Sample ID	Worker ID	Sample Number	Number of Replicates	Mean μ (dpm/1.4L)	Standard Deviation σ (dpm/1.4L)	Coefficient of Variation COV=100σ/μ (%)
1	1	1	4	0.646	0.209	32.3
2	2	1	2	0.340	0.031	9.1
3	3	1	3	0.862	0.543	63.`0
4	3	2	3	1.211	0.277	22.8
5	3	3	4	2.070	0.502	24.3
6	3	4	3	1.471	0.132	9.0
7	3	5	3	2.018	0.267	13.2
8	3	6	3	2.497	0.610	24.4
9	3	7	5	3.814	1.541	40.4
10	3	8	3	3.955	0.393	9.9
11	4	1	4	0.495	0.322	65.0
12	5	1	2	0.323	0.051	15.8
13	6	1	2	0.365	0.075	20.5
14	7	1	3	0.298	0.136	45.5
15	8	1	2	0.581	0.118	20.2

Table 7. Analysis of Replicated Measurements on 31 Urine Samples

Sample ID	Worker ID	Sample Number	Number of Replicates	Mean μ (dpm/1.4L)	Standard Deviation σ (dpm/1.4L)	Coefficient of Variation COV=100σ/μ (%)
16	8	2	2	0.646	0.067	10.3
17	9	1	4	0.564	0.332	58.8
18	10	1	3	0.400	0.075	18.9
19	11	1	9	0.458	0.316	69.1
20	11	2	4	0.601	0.318	52.9
21	11	3	9	0.856	0.168	19.7
22	12	1	2	0.451	0.228	50.6
23	13	1	4	0.892	0.258	28.9
24	13	2	4	0.983	0.065	6.6
25	13	3	4	1.282	0.163	12.7
26	13	4	2	1.367	0.231	16.9
27	13	5	6	0.608	0.239	39.3
28	13	6	4	0.603	0.087	14.4
29	13	7	4	0.793	0.112	14.1
30	13	8	4	1.593	0.207	13.0
31	13	9	4	11.833	0.931	7.9

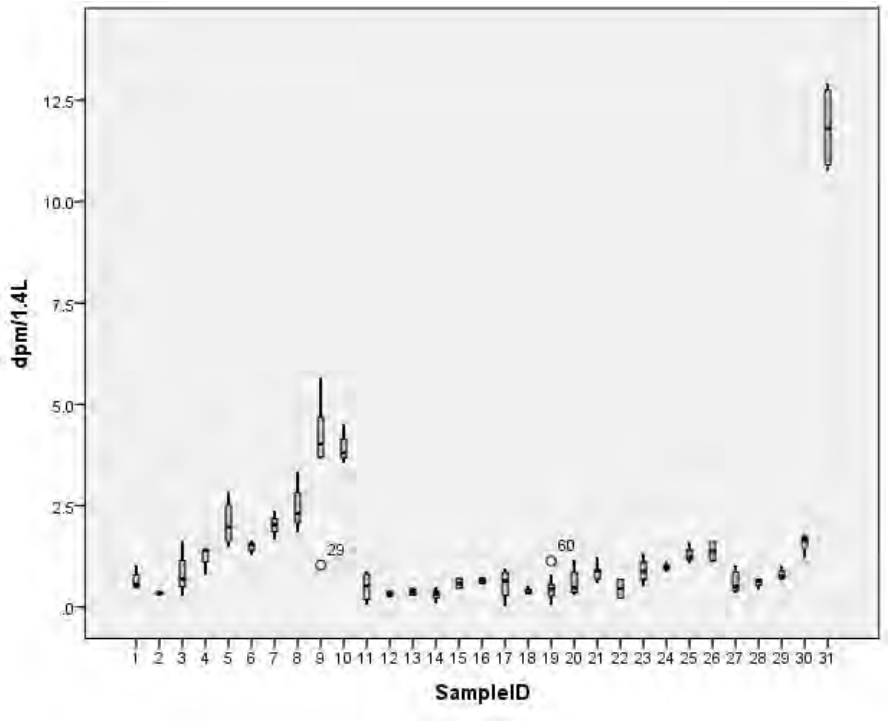


Figure 8. Box Plots Showing Spread of Replicated Measurements on 31 Bioassay Samples

(Outliers, shown as small circles, are identified by a Replicate ID Number.)

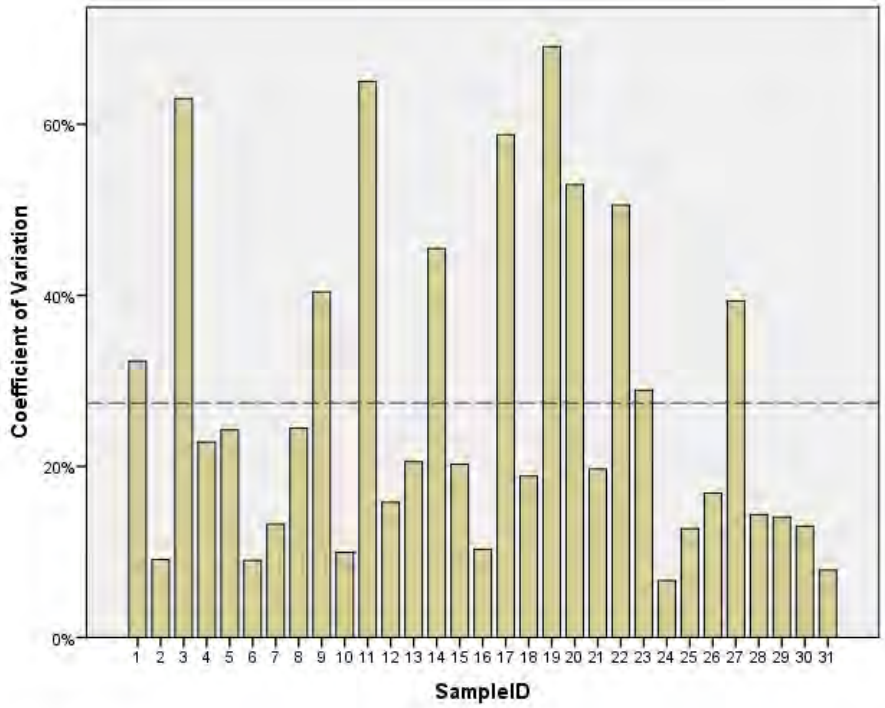


Figure 9. Coefficient of Variation (%) of Replicated Measurements on 31 Bioassay Samples

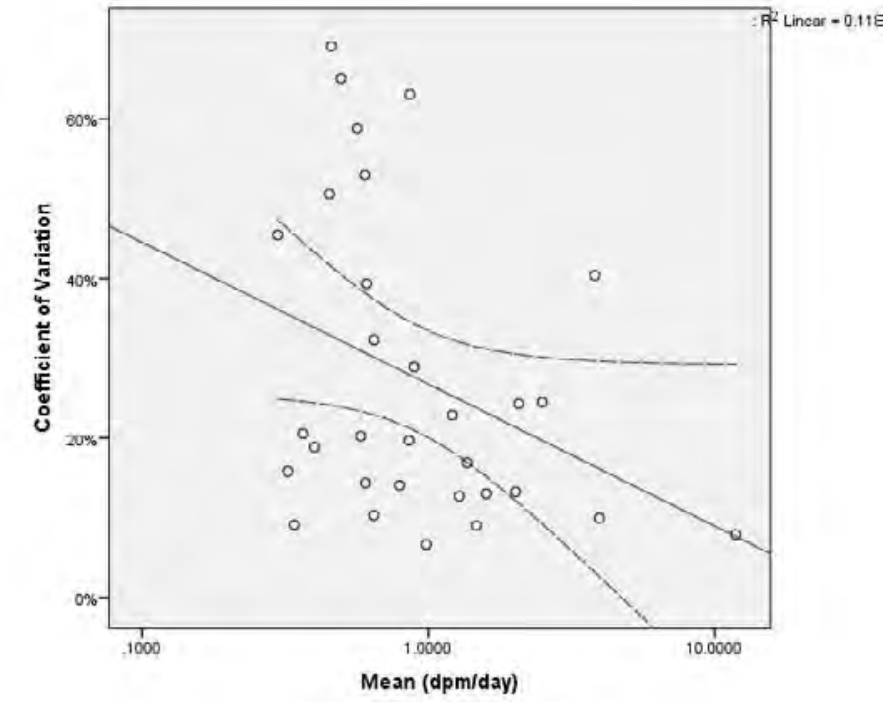


Figure 10. Coefficient of Variation (%) versus Mean of Replicate Measurements

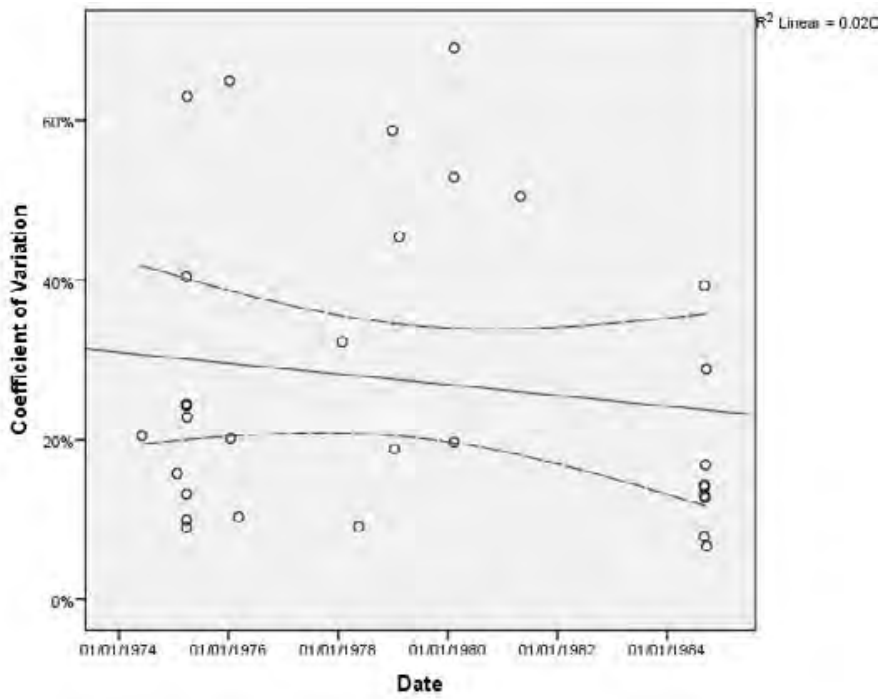


Figure 11. Coefficient of Variation (%) versus Date of Replicate Measurements

6.0 EFFECT OF THE VARIATION OF REPLICATES AND UNCERTAINTIES ON COMMITTED EQUIVALENT DOSES TO THE BONE SURFACE AND COMMITTED EFFECTIVE DOSES

As explained in Sections 4 and 5, there was a significant variation among the various disc results from the same aliquot sample for various workers. In RPRT-0055, the disc[1] results are averaged into a single bioassay result for the purposes of calculating an OPOS result and ultimately a coworker intake and dose analysis. In the case of monitored claimants, the "reported" result (as described in Section 4) is used for the purpose of retrospective dose reconstruction.

The maximum accepted uncertainty of a given measurement's precision and accuracy depends on the purpose of the result. In the case of the RPRT-0055, monitoring results are used to reconstruct SRS trivalent actinides committed equivalent doses to organs and tissues. The maximum acceptable range of activity concentrations in replicate aliquots from the same urine sample should be related to an acceptable range of committed equivalent doses to organs. This has not been formally defined by NIOSH.

ANSI 1996 suggests that:

> *In the routine monitoring of persons for radiation protection purposes, procedures must be established to ensure that workers have exposures measured and recorded with a reasonable degree of accuracy so that their exposures can be controlled and maintained ALARA, and so that they will not inadvertently during the course of their employment exceed the recommended and regulatory limits of quarterly or annual exposure.*

The same document points out that, "…it is difficult to rationally specify acceptable accuracy on the basis of radiation protection needs."

ANSI 1996 was revised in 2011 and does not carry the same advice, although the general philosophy is still present. ANSI 2011 states the following concerning adequate measurement techniques:

> *The goals of any quality-oriented measurement program are to establish credibility and to maintain the quality of results within established limits of acceptance. To achieve the goal of obtaining quality data, only validated standard operating procedures shall be used. Validation of procedure is a value judgment in which the performance parameters of the method are compared with the requirements for the analytical data. A method that is valid in one situation may not be valid in another. Requirements for the data are prerequisite and must be established at the beginning of the project planning process for procedure selection and validation. When data requirements are not considered properly, analytical measurement can be unnecessarily expensive, if the method chosen is*

[1] As explained previously, single void bioassay samples were split into multiple aliquots, which were then placed on "discs" for the purposes of separately counting each aliquot.

> *more accurate than required. On the other hand, if the procedure is less accurate than required, the measurement data become inadequate. If the accuracy of the procedure is unknown, then the measurement data becomes useless, thereby requiring re-measurement.*

NCRP 2009 states:

> *Measurement uncertainties for actinides in urine via alpha spectrometry, including all sources of error, in indirect bioassay measurements for activity at levels near MDA are in the range of 30 %. … uncertainties in classical (e.g., least-squares) analysis, however large, may still be unimportant for operational doses falling below one tenth of those limits. Ultimately, since Bayesian tools and expertise may not be widely available, each facility needs to determine and justify the level of complication and accompanying expense used in the routine calculation of doses.*

NCRP 2009 cites the OMINEX Project (Optimization of Monitoring for Internal Exposures), which conducted a survey of bioassay laboratories and specifically:

> *… compiled the results for 18 laboratories that responded (Hurtgen and Cossonnet, 2003). One goal was to determine the optimum analytical conditions, and the focus was on alpha-spectrometric measurements of the actinides, considered to be among the most challenging analyses routinely conducted. The optimum conditions were based on an uncertainty of <25 % for total activity of 1 mBq in a 24 h sample (urine) with an MDA of 0.1 mBq. The average reported by the participating laboratories was an uncertainty of 30 % for 1 mBq in a 24 h urine sample (Hurtgen and Cossonnet, 2003).*

The final report on the OMINEX project was published in 2004 as an NRPB W-60 document (Etherington et al. 2004). It states that:

> *The performance of a particular specification for monitoring (monitoring method(s), monitoring interval/times, etc.) can be judged against a defined minimum requirement on uncertainty in assessed dose.*

The EURADOS Report 2013-01 (Castellani et al. 2013) states that:

> *The effort applied to the evaluation of incorporation monitoring data should broadly correspond to the expected level of exposure, and the complexity of the case. On the one hand, if the exposure is likely to be very low with respect to the dose limits, simple evaluation procedures with a relatively high uncertainty may be applied. On the other hand, if the monitoring values indicate the exposure to be close to or even above the dose limits, much more sophisticated evaluation procedures will need to be applied. In routine monitoring, an explicit assessment of the dose is required only if the observed bioassay measurement exceeds a pre-defined critical monitoring quantity. This critical monitoring quantity MC can be*

> *considered as the amount of activity retained or excreted at the end of a monitoring period that determines an intake that, if it was repeated for all monitoring periods during the accounting year, would result in a value of committed effective dose of 0.1 mSv in a year. In the absence of knowledge of the exact time of intake, the adopted assumption is to consider that intake took place at the central value of the monitoring period (T/2), according to the indication of the ICRP publication 78 (ICRP 1997). A recent confirmation of this methodology is also reported in the ISO 20553 standard (ISO 2006). The MC for Am-241 is 3E-5 Bq/d for a maximum monitoring interval of 180 d. So in case of the actinides, any significant monitoring value is likely to result in an annual dose of more than 0.1 mSv and thus has to be evaluated.*

All the aforementioned documents suggest that the acceptable accuracy of monitoring results should depend on the pre-selected purpose of the use of those results. In general, urine bioassay monitoring results are used with the objective of radiation protection of workers, and the annual assessed doses from those measurements are compared with safe limits. For this reason, the accuracy of the bioassay method is established based on the capacity to detect intakes that result in committed effective doses of the order of 0.1 mSv (10 mrem).

NCRP 2009 suggested an uncertainty of <0.25% for a total activity of 1 mBq in a 24-h sample (urine), with an MDA of 0.1 mBq under optimum conditions. In the case of this review, the method used to measure the trivalent actinides in urine has a DL of 0.3 dpm/1.5L, about 5E-3 Bq/day, which is higher than both values suggested by NCRP 2009 to calculate the uncertainties. Thus, the uncertainty suggested by the NCRP 2009 does not apply, for two reasons:

- The method does not apply to the optimum conditions
- The objective on the use of the bioassay results is not the assessment of effective doses for radiation protection purposes

The "reported" bioassay results are used by NIOSH to calculate the intakes and committed equivalent doses to tissues and organs of individual claimant workers. In addition, they are also used to calculate coworkers' intakes and committed equivalent doses to be applied to unmonitored workers.

Assuming that the activity concentration in urine was due to intakes of Am-241, SC&A has evaluated the consequences of the variations on disc results in the committed equivalent doses to bone surface, which is the tissue with the highest committed dose per unit intake. This selection did not take into account the probability of cancer induction in bone surface as compared to other organs and tissues and thus the committed equivalent dose to bone surface was only used as an example. For this analysis, SC&A has focused on a 20–50 year committed equivalent dose using examples of variation in disc results with reported values near the DLs, as well as reported values much higher than the MDA. SC&A uses the term "variation" to mean the comparison of different disc results from the same urine sample. As there are many results calculated from only two discs, variation among discs was used instead of any other potential statistical measure of dispersion. The aim of the comparison is focused on the difference in committed equivalent

doses to the bone surface, calculated independently for each disc result from the same urine sample.

The analysis comparisons contained herein are only listed as examples. The validity of each bioassay result should be analyzed individually by NIOSH while taking into account the objective of the specific dose reconstruction or assignment of coworker intakes for the unmonitored worker. The following table (Table 8) contains selected examples on variations of disc results for reported results in the range of 0.3 to 1 dpm/1.5 L.

Table 8. Examples of the Variation of Disc Results Related to the Same Urine Sample (activities in dpm/1.5L)

Worker Identifier	Type	dpm/ 1.5L (1)	dpm/ 1.5L (2)	dpm/ 1.5L (3)	dpm/ 1.5L (4)	dpm/ 1.5L (5)	dpm/ 1.5L (6)	dpm/ 1.5L (7)	dpm/ 1.5L (8)	Report/ Average
A	Routine	0.588	1.036	0.535	0.123					0.6
L	Follow-up	0.479	0.594	0.511	1					0.6
K	Routine	0.621	0.079							0.35
W	Special	0.526	0.714	0.142	0.378					0.4
LO	Follow-up	1.03	-0.309	0.999	0.575					0.6
D	Special	0.24	0.92							0.6
D	Follow-up	0.357	0.04	0.656	0.099	1.609	1.423	1.144	0.8	0.8
E	Routine	0.435	0.534	0.615	1.03					0.7
H	Follow-up	0.333	0.679	1.094	0.806					0.7
J	4	0.627	0.341	0.96						0.6
D	2	0.312	1.19	0.352						0.6
B	Follow-up	0.558	1.253	0.926						0.9
IW	Special	0.304	1.598	0.684						0.9
J	Follow-up	0.922	0.523	1.047	0.656					0.8
WP	Follow-up	0.567	1.025	1.587	0.332					0.9
JE	Follow-up	0.44	0.697	1.27	1.245					0.9
I	Routine	1.455	0.376							0.9
B	Follow-up	0.312	0.602	1.31	0.528					0.6
R	Follow-up	1.015	0.412	0.948	0.614	0.416	0.741			0.7
RL	Routine	1.083	0.654	0.533						0.7

The following table (Table 9) of acute intakes was derived assuming an Am-241 concentration in urine equal to 0.3 dpm/1.5 L for samples taken at various times after intake. For example, if the concentration of Am -241 in urine was 0.3 dpm/1.5L at 2 days after the intake, the corresponding intake is 1.3×10^3 dpm (22 Bq). If the concentration of Am -241 in urine was 0.3 dpm/1.5 L at 10 days after the intake, the corresponding intake is 6.2×10^3 dpm (100 Bq). If the concentration of Am -241 in urine was 0.3 dpm/1.5 L at 60 days after the intake, the corresponding intake is 1.6×10^4 dpm (270 Bq).

The excretion of 1.5 liters may be considered as a daily excretion rate. ICRP Publication 23 (ICRP 1975) suggests an excretion rate of 1.4 liters per day for the standard man, while the most recent publication (ICRP 2002) suggests a standard daily excretion rate of 1.6 liters for adult males. The predicted activity fractions per unit intake in a 24-hour urine sample, as defined in ICRP 78 (ICRP 1997), were used in this analysis.

Table 9. Acute Intake of Am-241 Corresponding to an Excretion Rate of 0.3 dpm/d at Various Times Post-Exposure

Time After Acute Intake (days)	ICRP 78 Predicted Fraction of Intake in 24-h Urine	Intake Corresponding to the MDA (dpm)	Intake Corresponding to the MDA (Bq)
1	1.8E-03	1.7E+02	2.8E+00
2	2.3E-04	1.3E+03	2.2E+01
3	1.3E-04	2.3E+03	3.8E+01
4	9.0E-05	3.3E+03	5.6E+01
5	7.2E-05	4.2E+03	7.0E+01
6	6.3E-05	4.8E+03	8.0E+01
7	5.8E-05	5.2E+03	8.7E+01
8	5.4E-05	5.6E+03	9.3E+01
9	5.2E-05	5.9E+03	9.8E+01
10	4.9E-05	6.2E+03	1.0E+02
15	3.9E-05	7.7E+03	1.3E+02
30	2.6E-05	1.1E+04	1.9E+02
60	1.9E-05	1.6E+04	2.7E+02
90	1.6E-05	1.9E+04	3.2E+02
180	1.1E-05	2.7E+04	4.5E+02

The bone surface is the tissue receiving the highest committed dose resulting from intakes of Am-241. Table 10 shows the 20 to 50 year committed doses to the bone surface corresponding to the acute intakes of Am-241 shown in Table 9. The dose coefficients per unit intake were taken from the ICRP software *Database of Dose Coefficients: Workers and Members of the Public* (ICRP 2001).

Table 10. Committed Equivalent Doses to the Bone Surface from an Acute Intake of Am-241 Corresponding to an Excretion Rate of 0.3 dpm/day

Time* (Days)	Intake (Bq)	20-y Dose (rem)	25-y Dose (rem)	30-y Dose (rem)	40-y Dose (rem)	50-y Dose (rem)
1	2.8E+00	1.6E-01	1.9E-01	2.2E-01	2.7E-01	3.1E-01
2	2.2E+01	1.2E+00	1.5E+00	1.7E+00	2.1E+00	2.4E+00
3	3.8E+01	2.1E+00	2.6E+00	3.0E+00	3.7E+00	4.2E+00
4	5.6E+01	3.1E+00	3.8E+00	4.3E+00	5.4E+00	6.2E+00
5	7.0E+01	3.9E+00	4.7E+00	5.4E+00	6.7E+00	7.7E+00
6	8.0E+01	4.5E+00	5.4E+00	6.2E+00	7.6E+00	8.8E+00
7	8.7E+01	4.9E+00	5.9E+00	6.8E+00	8.3E+00	9.6E+00
8	9.3E+01	5.2E+00	6.3E+00	7.2E+00	8.9E+00	1.0E+01
9	9.8E+01	5.5E+00	6.6E+00	7.6E+00	9.4E+00	1.1E+01
10	1.0E+02	5.8E+00	7.0E+00	8.0E+00	9.9E+00	1.1E+01
15	1.3E+02	7.2E+00	8.7E+01	1.0E+01	1.2E+01	1.4E+01
30	1.9E+02	1.1E+01	1.3E+01	1.5E+01	1.8E+01	2.1E+01
60	2.7E+02	1.5E+01	1.8E+01	2.1E+01	2.6E+01	2.9E+01
90	3.2E+02	1.8E+01	2.1E+01	2.5E+01	3.1E+01	3.5E+01
180	4.5E+02	2.5E+01	3.1E+01	3.5E+01	4.4E+01	5.0E+01

*Time after intake, when urine sample was analyzed with a concentration of Am-241 in urine equal to 0.3 dpm/d

The following table (Table 11) shows the 30-year committed equivalent dose to bone surface for urine activity results varying from 0.3 dpm/1.5 L to 1.5 dpm/1.5 L. Using Table 11, it is possible to visualize the order of magnitude of the uncertainties on committed equivalent doses to the bone surface, produced for each bioassay result, if the disc results were used independently to calculate the dose.

Table 11. Predicted 30-Year Committed Equivalent Doses to the Bone Surface for Am-241 Urine Activities Ranging from 0.3 dpm/1.5 L to 1/5 dpm/1.5 L Utilizing Different Sampling Times after Intake

Time between Sample and Intake (days)	30-y Dose based on a Urine Activity of 0.3 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 0.6 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 0.9 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 1.2 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 1.5 dpm/1.5 L (rem)
1	2.2E-01	4.4E-01	6.6E-01	8.8E-01	1.1E+00
2	1.7E+00	3.4E+00	5.0E+00	6.7E+00	8.4E+00
3	3.0E+00	6.0E+00	8.9E+00	1.2E+01	1.5E+01
4	4.4E+00	8.7E+00	1.3E+01	1.7E+01	2.2E+01
5	5.4E+00	1.1E+01	1.6E+01	2.2E+01	2.7E+01
6	6.2E+00	1.2E+01	1.9E+01	2.5E+01	3.1E+01
7	6.8E+00	1.4E+01	2.0E+01	2.7E+01	3.4E+01
8	7.2E+00	1.4E+01	2.2E+01	2.9E+01	3.6E+01
9	7.6E+00	1.5E+01	2.3E+01	3.1E+01	3.8E+01
10	8.0E+00	1.6E+01	2.4E+01	3.2E+01	4.0E+01

Table 11. Predicted 30-Year Committed Equivalent Doses to the Bone Surface for Am-241 Urine Activities Ranging from 0.3 dpm/1.5 L to 1/5 dpm/1.5 L Utilizing Different Sampling Times after Intake

Time between Sample and Intake (days)	30-y Dose based on a Urine Activity of 0.3 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 0.6 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 0.9 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 1.2 dpm/1.5 L (rem)	30-y Dose based on a Urine Activity of 1.5 dpm/1.5 L (rem)
15	1.0E+01	2.0E+01	3.0E+01	4.0E+01	5.0E+01
30	1.5E+01	3.0E+01	4.5E+01	6.0E+01	7.5E+01
60	2.1E+01	4.2E+01	6.2E+01	8.3E+01	1.0E+02
90	2.5E+01	5.0E+01	7.5E+01	9.9E+01	1.2E+02
180	3.6E+01	7.1E+01	1.1E+02	1.4E+02	1.8E+02

For example, for worker J in Table 8, one bioassay sample produced three disc results of approximately 0.3, 0.6, and 0.9 dpm/1.5 L. If those results were analyzed independently, and if the urine sample was taken 10 days after the intake, a variation from 0.3 to 0.6 dpm/1.5 L produces an increase of 8 rem in the 30-year committed dose to the bone surface (increase from 8 rem to 16 rem). If the sample was taken 30 days after the intake instead of 10 days, the uncertainty in the 30-year committed dose to the bone is 15 rem (increase in bone surface dose from 15 rem to 30 rem). In addition, a variation in urine result from 0.3 to 0.9 dpm/1.5 L produces an increase in bone surface dose of 16 rem (sample taken 10 days after intake) and 30 rem (sample taken 30 days after the intake).

Similarly, for worker D in Table 8, one bioassay sample produced 3 disc results of approximately 0.3, 1.2, and 0.3 dpm/1.5 L. A variation from 0.3 to 1.2 dpm/1.5 L for a sample taken 10 days after the intake results in an increase of 24 rem in the committed 30-year dose to the bone (an increase from 8 rem to 32 rem). If the sample was taken 30 days after the intake, there is a 45 rem increase (an increase from 15 rem to 60 rem).

As seen in Table 8, there were various disc results from the same sample of urine with variations similar to the variations shown in the above examples. In general, derivation of coworker intakes and doses assumes a continuous or chronic intake. If one assumes a continuous intake of Am-241 during a 1-year period with a sample taken at the end of the year, the committed equivalent doses to the bone surface can be derived for urine results varying from 0.3 to 1.5 dpm/1.5 L, the results of which are shown in Table 12.

Table 12. Committed Equivalent Doses to the Bone Surface Calculated Assuming a Continuous Intake of Am-241 during One Year for Sampling Results Ranging from 0.3 to 1.5 dpm/1.5 L

Bioassay Result (dpm/1.5L)	20y Dose to the Bone Surface (rem)	25y Dose to the Bone Surface (rem)	30y Dose to the Bone Surface (rem)	40y Dose to the Bone Surface (rem)	50y Dose to the Bone Surface (rem)
0.3	1.4E+01	1.7E+01	2.0E+01	2.4E+01	2.8E+01
0.6	2.8E+01	3.4E+01	3.9E+01	4.9E+01	5.6E+01
0.9	4.2E+01	5.1E+01	5.9E+01	7.3E+01	8.4E+01
1.2	5.6E+01	6.8E+01	7.9E+01	9.7E+01	1.1E+02
1.5	7.0E+01	8.5E+01	9.8E+01	1.2E+02	1.4E+02

As seen in Table 12, a variation from 0.3 to 1.5 dpm/1.5 L of Am-241 in a bioassay result produces an increase of 59 rem in the 30-year committed equivalent dose to the bone surface (an increase from 20 rem to 79 rem).

As the urine results became significantly higher than the MDA, the uncertainty in the committed doses due to differences in disc results become more significant. Table 13 provides several examples of observed variations in disc results from the same urine sample where the activity in each disc is much higher than the MDA.

Table 13. Examples of Observed Variations in Disc Results of the Same Sample that are Significantly Higher than the MDA (0.3 dpm/1.5 L)

Worker Identifier	Type	dpm/1.5L (1)	dpm/1.5L (2)	dpm/1.5L (3)	dpm/1.5L (4)	dpm/1.5L (5)	dpm/1.5L (6)	Report/ Average
BL1	Follow-up	3.58	4.14	1.65	1.95			2.8
BL2	Follow-up	1.4	3.93	1.17				2.2
B	Follow-up	1.361	1.899	1.547	2.996	2.41	3.076	2.2
J	Follow-up	2.425	3.1	2.503	1.314	1.434		2
BR	Follow-up	1.28	0.862	2.142	2.872			1.8
W	Special	1.863	3.321	2.306				2.5

Table 14 shows the 30-year committed equivalent doses to the bone surface from Am-241 activity urine results varying from 1.2 dpm/1.5 L and 3.9 dpm/1.5 L.

Table 14. 30-Year Committed Equivalent Doses to the Bone Surface for Different Urine Activities and Different Sampling Collection Times

Time Between Sample and Intake (days)	30-Year Committed Equivalent Dose to the Bone Surface (rem) Based on Sample Activities Ranging from 1.2 to 3.9 dpm/1.5 L						
	1.2 dpm/1.5L	1.5 dpm/1.5L	1.8 dpm/1.5L	2.1 dpm/1.5l	2.4 dpm/1.5L	3.6 dpm/1.5L	3.9 dpm/1.5L
1	8.8E-01	1.1E+00	1.3E+00	1.5E+00	1.8E+00	2.6E+00	2.9E+00
2	6.7E+00	8.4E+00	1.0E+01	1.2E+01	1.3E+01	2.0E+01	2.2E+01
3	1.2E+01	1.5E+01	1.8E+01	2.1E+01	2.4E+01	3.6E+01	3.9E+01
4	1.7E+01	2.2E+01	2.6E+01	3.0E+01	3.5E+01	5.2E+01	5.7E+01
5	2.2E+01	2.7E+01	3.3E+01	3.8E+01	4.4E+01	6.5E+01	7.1E+01
6	2.5E+01	3.1E+01	3.7E+01	4.3E+01	5.0E+01	7.4E+01	8.1E+01
7	2.7E+01	3.4E+01	4.1E+01	4.7E+01	5.4E+01	8.1E+01	8.8E+01
8	2.9E+01	3.6E+01	4.3E+01	5.1E+01	5.8E+01	8.7E+01	9.4E+01
9	3.1E+01	3.8E+01	4.6E+01	5.3E+01	6.1E+01	9.2E+01	9.9E+01
10	3.2E+01	4.0E+01	4.8E+01	5.6E+01	6.4E+01	9.6E+01	1.0E+02
15	4.0E+01	5.0E+01	6.0E+01	7.0E+01	8.0E+01	1.2E+02	1.3E+02
30	6.0E+01	7.5E+01	8.9E+01	1.0E+02	1.2E+02	1.8E+02	1.9E+02
60	8.3E+01	1.0E+02	1.2E+02	1.5E+02	1.7E+02	2.5E+02	2.7E+02
90	9.9E+01	1.2E+02	1.5E+02	1.7E+02	2.0E+02	3.0E+02	3.2E+02
180	1.4E+02	1.8E+02	2.1E+02	2.5E+02	2.8E+02	4.3E+02	4.6E+02

For Worker BL2 in Table 13, one bioassay result produced 3 disc results of 1.4, 3.9, and 1.17 dpm/1.5 L. If those results were analyzed independently and it is assumed the urine sample was taken 10 days after the intake, a variation from 1.2 dpm/1.5 L to 3.9 dpm/1.5 L produces an increase of 68 rem in the committed 30-year dose to the bone surface (an increase from 32 rem to 100 rem). If the sample was taken 30 days after the intake, the uncertainty in the 30-year committed effective dose to the bone surface is 130 rem (the dose increases from 60 rem to 190 rem).

The following table (Table 15) shows the variation in committed effective doses for continuous Am-241 intake during 1 year with an end-of-the-year sample activity ranging from 1.2 to 3.9 dpm/1.5 L. As previously stated, the derivation of coworker intakes and doses assumes a continuous/chronic exposure.

Table 15. Committed Effective Doses to the Bone Surface Calculated Assuming a Continuous Intake during One Year for Varying Sample Activities

Sample Activity (dpm/1.5L)	20y dose (rem)	25y dose (rem)	30y dose (rem)	40y dose (rem)	50y dose (rem)
1.2	5.6E+01	6.8E+01	7.9E+01	9.7E+01	1.1E+02
1.5	7.0E+01	8.5E+01	9.8E+01	1.2E+02	1.4E+02
1.8	8.4E+01	1.0E+02	1.2E+02	1.5E+02	1.7E+02
2.1	9.8E+01	1.2E+02	1.4E+02	1.7E+02	2.0E+02
2.4	1.1E+02	1.4E+02	1.6E+02	1.9E+02	2.3E+02
2.7	1.3E+02	1.5E+02	1.8E+02	2.2E+02	2.5E+02
3.0	1.4E+02	1.7E+02	2.0E+02	2.4E+02	2.8E+02
3.3	1.5E+02	1.9E+02	2.2E+02	2.7E+02	3.1E+02
3.6	1.7E+02	2.0E+02	2.4E+02	2.9E+02	3.4E+02
3.9	1.8E+02	2.2E+02	2.6E+02	3.2E+02	3.7E+02

Table 15 shows that when the Am-241 activity concentration in urine varies from 1.2 to 3.9 dpm/1.5 L, the derived 30-year committed effective doses to bone surface varies from 79 rem to 260 rem.

Tables 11–15 are only examples of the fluctuation in committed effective doses to the bone surface when disc results are evaluated independently. The tables show the dependency of the bone surface dose on the uncertainties in the bioassay results. NIOSH should analyze the differences in disc results of each bioassay result and evaluate their influence on the ability to calculate equivalent doses to various tissues and organs, as well as the consequences in terms of calculating the probability of causation.

In a similar way, NIOSH should analyze the bioassay results with significant differences in disc values and determine their influence on the ability of deriving coworker intakes for the unmonitored worker. It also must be noted that there are many urine sample results with very high activity as a consequence of the treatment with DTPA. Some of those samples show very large discrepancies among discs from the same urine sample. Those results cannot be used to calculate doses using the standard ICRP models. They also should not be used to calculate coworker intake and are thus outside the scope of this review.

In conclusion, SC&A has pointed out that the SRS method to analyze urine samples for the trivalent actinides carries significant variation among the various disc results from the same sample. The acceptable accuracy of monitoring results depends on the pre-selected purpose on the use of those results. Using Am-241 as an example, SC&A has shown that variations in activity concentrations in the same bioassay sample produce significant uncertainties in committed equivalent doses to the bone surface.

Finding 15: NIOSH must demonstrate the usability of the bioassay reported results for trivalent actinides in terms of retrospective dose calculations for the individual claimants. Each claim

must be analyzed case-by-case, taking into consideration the organ or tissue for which the committed effective dose is calculated and its probability of causation.

Finding 16: NIOSH should review the number of bioassay samples that carry large discrepancies in disc activity concentrations, as well as the magnitude of variation in activity concentration in individual disc results, in order to establish the adequacy of the available records to derive the 50^{th}, 84^{th} and 95^{th} percentile coworkers' intakes for the trivalent actinides.

7.0 COMPARISON OF CTW INTAKES WITH AMW COWORKER MODEL

SC&A identified several claimants among the monitored subcontractor population who also had at least one positive reported bioassay sample. These claims were examined and intake analyses were performed for comparison against the 95th percentile coworker assignment. If an incident was identified in the claimant record, the date of the incident was used to calculate an acute intake. If no specific incident was identified, both a chronic intake scenario and an acute intake scenario were evaluated. For the chronic intake scenario, it was assumed that the claimant was exposed beginning in 1973 up through the date of the positive bioassay sample. Acute intake evaluations assume that the intake occurred midway between the positive bioassay sample and the previous sample. This is in accordance with the ICRP recommendations for situations in which the exact date of the intake is unknown. The intake evaluations for each identified claimant are presented below. Overall findings based on this analysis are presented at the end of this section.

7.1 CLAIM #[3]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted] & [Redacted]

The claimant was involved in an acute curium incident in March of 1975. The trivalent bioassay results for this claimant during the SEC period are shown in Table 16.

Table 16. Trivalent Urinalysis Results during SEC Period for Claim #[3]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)[a]	Logbook Report Value[b]	NOCTS Result[c]	
5/25/[redact]	0	<0.3	<0.3	
1/31/[redact]	0	<0.3	<0.3	
5/16/[redact]	0	<0.3	<0.3	
11/7/[redact]	0	<0.3	<0.3	
3/27/[redact]	3.699, 5.64, 4.02, 1.033, 4.68	3.6	3.2, 1.7, 50	Note: NOCTS results do not agree with logbook results. Values in "Logbook Report Value" column appear in the coworker database and correspond to values contained in the "Remarks Column" of the hardcopy record. Incident occurred on this date. Sample designation: "Special"
3/27/[redact]	1.863, 3.321, 2.306	2.5	3.2, 1.7, 50	Note: NOCTS results do not agree with logbook results. Values in "Logbook Report Value" column appear in the coworker database and correspond to values contained in the "Remarks Column" of the hardcopy record. Sample designation: "Special"
3/27/[redact]	3.798, 4.496, 3.572	4	3.2, 1.7, 50	Note: NOCTS results do not agree with logbook results. Values in "Logbook Report Value" column appear in the coworker database and correspond to values contained in the "Remarks Column" of the hardcopy record. Sample designation: "Special"

Table 16. Trivalent Urinalysis Results during SEC Period for Claim #[redact]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)[a]	Logbook Report Value[b]	NOCTS Result[c]	
3/28/[redact]	2.208, 2.82, 1.75, 1.5	1.4	50	Note: NOCTS results do not agree with logbook results Sample designation: "Follow-up"
3/28/[redact]	1.52, 1.603, 1.29	1.5	50	Note: NOCTS results do not agree with logbook results Sample designation: "Special"
3/28/[redact]	2.339, 2.029, 1.685	2	50	Note: NOCTS results do not agree with logbook results Sample designation: "Special"
3/31/[redact]	1.409, 1.405, 0.82	1.2	1.2	Sample designation: "Special"
4/1/[redact]	0.304, 1.598, 0.684	0.9	0.9	Sample designation: "Special"
5/5/[redact]	0, 0.57	<0.3	<0.3	Note: Positive measurements mixed with "0" measurements. Sample designation: "Follow-up"
5/7/[redact]	0, 0.586	<0.3	<0.3	Sample designation: "Follow-up"
6/2/[redact]	0.194	<0.3	<0.3	
9/4/[redact]	0.093	<0.3	<0.3	
11/20/[redact]	0	<0.3	<0.3	
2/5/[redact]	0	<0.3	<0.3	
5/27/[redact]	0.07	<0.3	<0.3	Sample designation: "5" Record in NOCTS is listed as "Pu," but lists the MDA for "Am" of <0.3 and not the "Pu" MDA of <0.3.
11/5/[redact]	0	<0.3	<0.3	
5/13/[redact]	0	<0.3	<0.3	Sample designation: "5"
2/21/[redact]	0.095	<0.3	<0.3	Sample designation: "12"
1/7/[redact]	Missing	Missing	<0.3	
12/14/[redact]	Missing	Missing	<0.3	

a These represent the normalized aliquot measurements in dpm/1.5 L found in the electronic coworker database transcribed by NIOSH/ORAUT from hardcopy bioassay logbooks.
b Each logbook entry also contained a "reported" value in addition to the raw results shown in column 2.
c This column represents the data provided by DOE for the individual claim for the purposes of dose reconstruction.

7.1.1 Intake Scenarios Considered

Claimant was involved in an intake incident involving Cm-244 in Cell 8 of 773A (see redacted incident report in Figure 12). Based on the incident report, the resulting bioassay results were reported as:

3/27/[redact]: 3.2 dpm/1.5L
3/28/[redact]: 1.7 dpm/1.5L
3/31/[redact]: 1.2 dpm/1.5L
4/1/[redact]: 0.9 dpm/1.5L

It must be noted that these results are not compatible with the expected decrease in excretion rates for Type M Cm-244, applying ICRP 71 biokinetic model (ICRP 1995). One would expect the urinalysis sample to be approximately 20 times lower on March 31st than it was on March

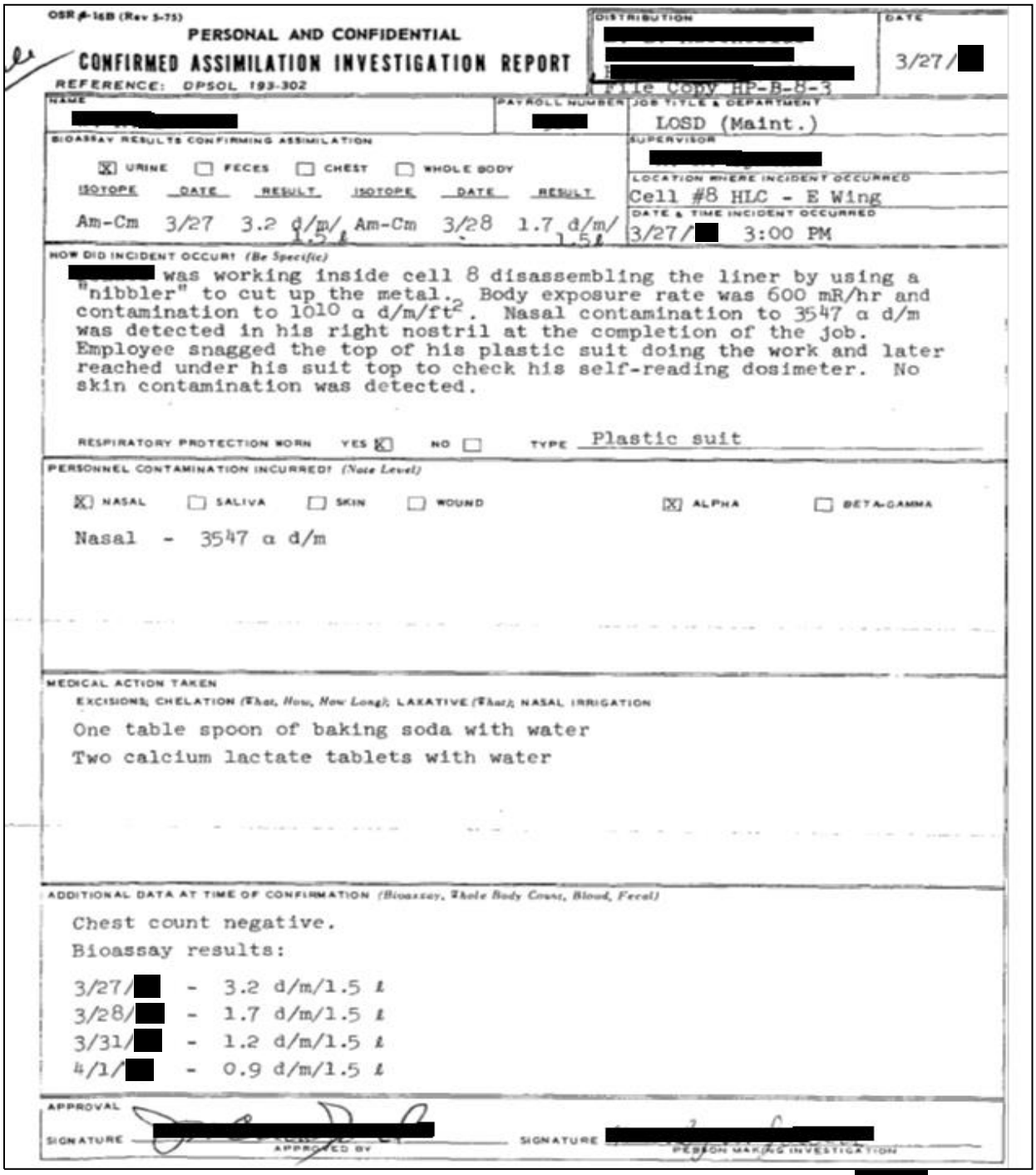
28th. Nonetheless, the most claimant-favorable intake rates were calculated using variable combinations of the four results listed in the incident report (note Additional Comments). For the purposes of this analysis, 1.5 liters was considered to be the daily excretion rate.[2] The summary of modeled intakes is shown in Table 17.

Table 17. Summary of Modeled Intakes

Type of Intake	Date of Intake	Total Intake/ Intake Rate	Additional Comments
Acute	3/27/[redact]	4.5E+03 dpm	Only considers the sample taken on 3/27/[redact].
Acute	3/27/[redact]	1.3E+04 dpm	Only considers the samples taken on 3/31/[redact] and 4/1/[redact] and ignores the results on 3/27/[redact] and 3/28/[redact].
Acute	3/27/[redact]	7.86E+03 ± 77.9% dpm	Utilizes the "Point Estimate" method of bioassay fitting.
Acute	3/27/[redact]	1.5E+03 dpm	Utilizes the unweighted least squares fit method.

ORAUT 2013 assigns a Cm-244 coworker intake of 19.3 dpm/d, which results in a total annual intake of 7,044 dpm. This value is compatible with the point estimate calculated intake rate based on the acute incident intake (7,860 dpm), which was the most claimant-favorable calculated intake based on all four results. The highest modeled acute intake (13,000 dpm) is a factor of 2 higher than the 95th percentile coworker intakes; however, this is deemed acceptable considering the error associated with discarding the samples on the 27th and 28th.

[2] ICRP Publication 23 (1975) reports 1.4 liters as the daily excretion rate, while ICRP Publication 89 (2001) reports 1.6 liters as the daily excretion rate.



PERSONAL AND CONFIDENTIAL

CONFIRMED ASSIMILATION INVESTIGATION REPORT

REFERENCE: DPSOL 193-302

DISTRIBUTION: [redacted] File Copy HP-B-8-3

DATE: 3/27/[redacted]

NAME: [redacted]

PAYROLL NUMBER: [redacted]

JOB TITLE & DEPARTMENT: LOSD (Maint.)

BIOASSAY RESULTS CONFIRMING ASSIMILATION

☒ URINE ☐ FECES ☐ CHEST ☐ WHOLE BODY

ISOTOPE	DATE	RESULT	ISOTOPE	DATE	RESULT
Am-Cm	3/27	3.2 d/m/1.5 ℓ	Am-Cm	3/28	1.7 d/m/1.5 ℓ

SUPERVISOR: [redacted]

LOCATION WHERE INCIDENT OCCURRED: Cell #8 HLC - E Wing

DATE & TIME INCIDENT OCCURRED: 3/27/[redacted] 3:00 PM

HOW DID INCIDENT OCCUR? (Be Specific)

[redacted] was working inside cell 8 disassembling the liner by using a "nibbler" to cut up the metal. Body exposure rate was 600 mR/hr and contamination to 10^{10} α d/m/ft^2. Nasal contamination to 3547 α d/m was detected in his right nostril at the completion of the job. Employee snagged the top of his plastic suit doing the work and later reached under his suit top to check his self-reading dosimeter. No skin contamination was detected.

RESPIRATORY PROTECTION WORN: YES ☒ NO ☐ TYPE: Plastic suit

PERSONNEL CONTAMINATION INCURRED? (Note Level)

☒ NASAL ☐ SALIVA ☐ SKIN ☐ WOUND ☒ ALPHA ☐ BETA-GAMMA

Nasal - 3547 α d/m

MEDICAL ACTION TAKEN

EXCISION; CHELATION (What, How, How Long); LAXATIVE (What); NASAL IRRIGATION

One table spoon of baking soda with water

Two calcium lactate tablets with water

ADDITIONAL DATA AT TIME OF CONFIRMATION (Bioassay, Whole Body Count, Blood, Fecal)

Chest count negative.

Bioassay results:

3/27/[redacted] - 3.2 d/m/1.5 ℓ

3/28/[redacted] - 1.7 d/m/1.5 ℓ

3/31/[redacted] - 1.2 d/m/1.5 ℓ

4/1/[redacted] - 0.9 d/m/1.5 ℓ

APPROVAL

SIGNATURE [redacted] APPROVED BY

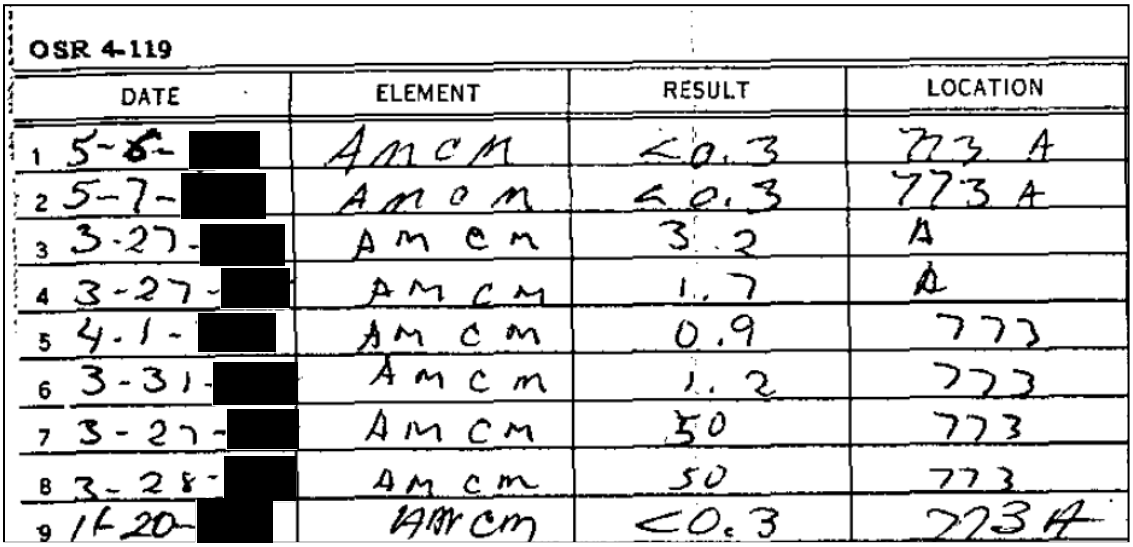
SIGNATURE [redacted] PERSON MAKING INVESTIGATION

Figure 12. Incident Report for Cm-244 Intake Occurring on 3/27/[redact]

7.1.2 Additional Comments

One particularly difficult challenge in calculating hypothetical intake scenarios based on the documented incident is the quality of the available monitoring data. As noted in Table 16, the NOCTS bioassay records do not agree with the logbook results (either "raw" or "report" results)

on March 27 and March 28. Most significant is that the NOCTS records contain measurements on both March 27 and March 28 of 50 dpm/1.5 L (see Figure 13).

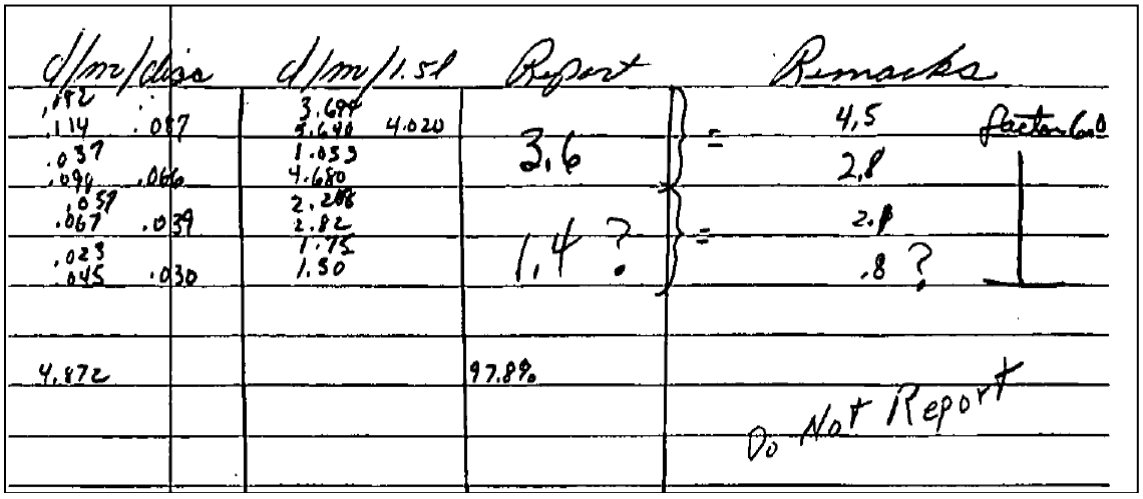


OSR 4-119

	DATE	ELEMENT	RESULT	LOCATION
1	5-6-[redacted]	Am Cm	<0.3	773 A
2	5-7-[redacted]	Am Cm	<0.3	773 A
3	3-27-[redacted]	Am Cm	3.2	A
4	3-27-[redacted]	Am Cm	1.7	A
5	4-1-[redacted]	Am Cm	0.9	773
6	3-31-[redacted]	Am Cm	1.2	773
7	3-27-[redacted]	Am Cm	50	773
8	3-28-[redacted]	Am Cm	50	773
9	1-20-[redacted]	Am Cm	<0.3	773 A

Figure 13. Bioassay Record Located in Claimant's NOCTS File

The logbook results for this worker and dates in question are shown in Figures 14–15. As seen in Figure 14, the results were clearly called into question by the laboratory and the report indicates "Do Not Report." These results were included in the coworker model database. The original logbook record also contains the notation, "See Page 165, 4-15-75 Am" (not shown in Figure 14). "Page 165" is shown in Figure 15.



d/m/dis	d/m/1.5 l	Report	Remarks
.192	3.694		
.114 .087	3.640 4.020		4,5 factor 6.0
.037	1.053	3.6	=
.094 .066	4.680		2.8
.059	2.208		
.067 .039	2.82		= 2.8
.023	1.75	1.4?	
.045 .030	1.50		.8?
4.872		97.8%	
			Do Not Report

Figure 14. Logbook Record Showing Results for 3/27 and 3/28. Record indicates "Do Not Report"

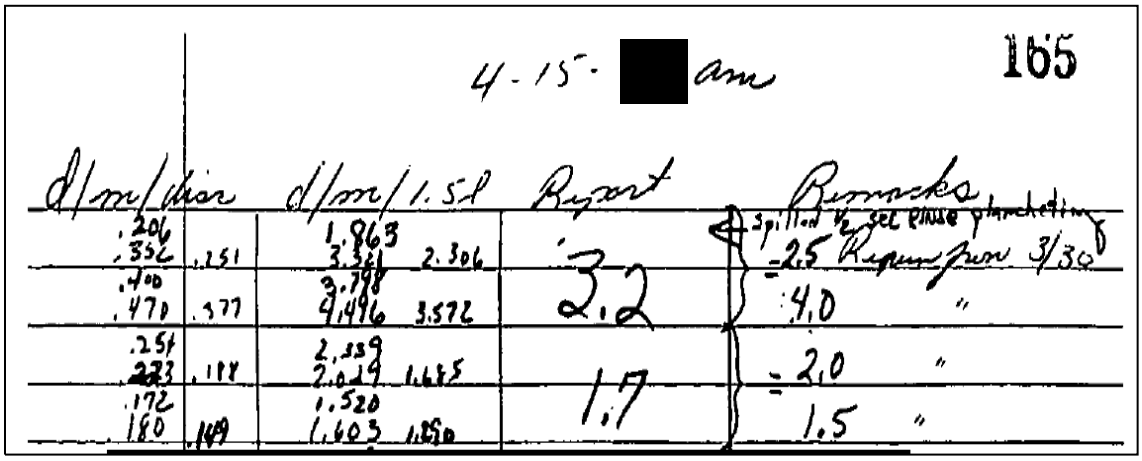


Figure 15. Additional Logbook Entries for Claimant Samples on 3/27 and 3/28

7.1.3 Conclusion

In summary, the assignment of the 95th percentile coworker intake rate on an annual basis is comparable to the calculated acute intake based on the four post-accident bioassay samples taken. However, SC&A noted significant data quality issues, which make an accurate estimate on intake difficult to obtain.

7.2 CLAIM #[1]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 18 displays the claimant's trivalent bioassay sampling during the SEC period. No indication of any incident preceding the positive sample on January 27, [redact], was identified; however, the sample taken on the preceding day was designated as "special."

Table 18. Trivalent Urinalysis Results during SEC Period for Claim #[1]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
1/26/[redact]	0.435, 0, 0.049	<0.3	<0.3	Sample Designation: "Special", special in vivo count also conducted on this day with no positive result.
1/27/[redact]	0.479, 0.594, 0.511, 1	0.6	0.6	Sample Designation: "Follow-up"
5/14/[redact]	Missing	Missing	<0.3	
4/30/[redact]	-0.151	<0.3	<0.3	
12/14/[redact]	Missing	Missing	<0.3	
4/29/[redact]	0.217	<0.3	<0.3	
5/12/[redact]	0.036	<0.3	<0.3	
4/27/[redact]	-0.022	<0.3	<0.3	
5/24/[redact]	-0.215	<0.3	<0.3	
4/20/[redact]	Missing	Missing	<0.3	

7.2.1 Intake Scenarios Considered

The samples shown in Table 19 for 1/26 and 1/27/[redact] were labelled "special" and "follow up," respectively. Although no documentation was identified in the file as to what special work may have been done or if there was an incident-driven intake, SC&A has assumed that the exposure occurred on 1/26 and was first identified in the follow-up sample on 1/27. It should be noted that one of the disc results taken on 1/26 was measured as positive (0.435 dpm/d); however, the overall average was less than the MDA of 0.3 dpm/d.

Table 19. Summary of Modeled Intakes

Type of Intake	Date of Intake	Total Intake/ Intake Rate	Additional Comments
Acute	1/26/[redact]	3.4E+02 dpm	Intake assumed to be Am-241
Acute	1/26/[redact]	3.4E+02 dpm	Intake assumed to be Cm-244
Acute	1/26/[redact]	4.6E+02 dpm	Intake assumed to be Cf-252

7.2.2 Additional Comments

Based on Table 18, it appears the claimant was on a routine annual monitoring program beginning in 1984 with samples collected around April/May of each year. All the results of these annual samples were below the DL. The 95th percentile intake rates based on the coworker model would predict urinary excretion rates below MDA for Cm and Am in the first 10 years of exposure.

Similar to Case #[3], data quality problems complicate the calculation of accurate intake assessments. For example, it can be seen in Table 19 that the day of the assumed intake, the claimant submitted a sample that was counted three times. Those results yielded one result above the MDA (0.435 dpm/d), 1 result below the MDA (0.049, an order of magnitude lower than the first measurement), and one result of zero. Additionally, the positive result on January 27th was measured five separate times (all of them positive measurements). The results varied by over a factor of 2 and ranged from 0.479 dpm/d up to 1 dpm/d.

7.2.3 Conclusion

The 95th percentile annual coworker intakes are 6,100/7,100/25,000 dpm for Am/Cm/Cf, respectively. In each case, the annual 95th percentile coworker intake assignment bounds the calculated intake based on an acute exposure on January 26, [redact], as shown in Table 19.

7.3 CLAIM #[2]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 20 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result was observed on May 18, [redact]; the next sample taken was nearly 3 years later. The NOCTS file for this claimant notes three separate contamination incidents; however, none of the incidents appears to have resulted in an intake of trivalent actinides.

Table 20. Trivalent Urinalysis Results during SEC Period for Claim #[2]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
2/7/[redact]	0.026	<0.3	<0.3	
7/12/[redact]	0	<0.3	<0.3	
10/15/[redact]	0	<0.3	<0.3	Sample Designation: "Special"
1/28/[redact]	0	<0.3	<0.3	
7/8/[redact]	0	<0.3	<0.3	
1/9/[redact]	0.078	<0.3	<0.3	
7/8/[redact]	0.06	<0.3	<0.3	
1/7/[redact]	0	<0.3	<0.3	
7/6/[redact]	Missing	Missing	<0.3	
4/11/[redact]	0	<0.3	<0.3	
5/18/[redact]	0.371, 0.309	0.3	0.3	
3/14/[redact]	0	<0.3	<0.3	
10/27/[redact]	0.026	<0.3	<0.3	
8/20/[redact]	0	<0.3	<0.3	
8/23/[redact]	-0.081	<0.3	<0.3	
8/7/[redact]	-0.037	<0.3	<0.3	

7.3.1 Intake Scenarios Considered

Table 21 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 21, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.23 dpm/d on the day of the observed positive sample (reported as 0.3 dpm/d in NOCTS). Additionally, if the positive result is assumed to be caused by an acute exposure occurring midway between the positive and previous sample, the resulting intake is approximately a factor of 5 larger than the 95th percentile chronic coworker assignment over a full year of chronic exposure.

Table 21. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]– 5/18/[redact]	16.7 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.23 dpm/d on the date of the positive sample (5/18/[redact]).
Acute	10/29/[redact]	3E+04 dpm	Date of intake assumed to be half way between positive sample and prior sample (201 days prior to the positive sample). 95th percentile coworker intake over the 201-day period totals 3.36E+03 dpm.

7.3.2 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample, the total acute intake is roughly an order of magnitude higher than the 95th percentile intake assignment.

7.4 CLAIM #[4]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 22 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result was observed on January 8, [redact]; the next sample taken was a few months later. The sample on July 8, [redact], also contained one disc measurement that was positive; however, the other two measurements for that sample were zero.

Table 22. Trivalent Urinalysis Results during SEC Period for Claim #[4]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
1/31/[redact]	0	<0.3	<0.3	
7/16/[redact]	0	<0.3	<0.3	
1/12/[redact]	Blank	<0.3	<0.3	Date appears as 1/7/[redact] in claimant record
7/9/[redact]	0	<0.3	<0.3	Date appears to be 3/9/[redact] in claimant record
1/10/[redact]	0	<0.3	<0.3	
7/9/[redact]	0	<0.3		
10/20/[redact]	0.192	<0.3	<0.3	
1/8/[redact]	0.076, 0.746, 0.295, 0.864	0.5	0.5	
4/23/[redact]	0	<0.3	<0.3	Sample Designation: "Resample"
7/8/[redact]	0, 0.337, 0	<0.3	<0.3	
1/7/[redact]	0	<0.3	<0.3	
1/12/[redact]	0	<0.3	<0.3	Date appears as 1/12/[redact] in claimant record
3/16/[redact]	0	<0.3	<0.3	

7.4.1 Intake Scenarios Considered

Table 23 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 23, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.23 dpm/d on the day of the observed positive sample (reported as 0.3 dpm/d in NOCTS). Additionally, if the positive result is assumed to be caused by an acute exposure occurring midway between the positive and previous sample, the resulting intake is approximately an order of magnitude larger than the 95th percentile chronic coworker assignment over the same period.

Table 23. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]–1/8/[redact]	16.7 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.2 dpm/d on the date of the positive sample (1/8/[redact]).
Acute	11/29/[redact]	2.2E+04 dpm	Date of intake assumed to be half way between positive sample and prior sample (40 days prior to the positive sample). 95th percentile coworker intake over a 1 year period totals approximately 6E+03 dpm.

7.4.2 Additional Comments

As can be seen in Table 22, the positive result on January 8, 1976, had highly variable individual disc measurements, which varied by over an order of magnitude (0.076 to 0.864 dpm/d). Additionally, it was noted that one other sample had a positive disc result (0.337 dpm/d), but was reported as <0.3 since the other two measurements were zero.

7.4.3 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample (40 days), the total intake is roughly a factor of 4 higher than the 95th percentile intake totaled over 1 year.

7.5 CLAIM #[5]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 24 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result was observed on January 23, [redact]; the next sample was taken roughly 6 months later on July 25, [redact]. That sample also contained a positive disc measurement; however, the other two measurements for that sample were less than the MDA, so the reported result was <0.3. None of the claimant's samples were labelled as "special" or "resample" or "follow-up." Notably, the claimant was monitored twice a year every year from [redact]–[redact], but not past this timeframe. The claimant was counted via in vivo in [redact] and [redact] with results below the MDA.

Table 24. Trivalent Urinalysis Results during SEC Period for Claim #[5]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
2/12/[redact]	0	<0.3	<0.3	
7/27/[redact]	0.12	<0.3	<0.3	
1/10/[redact]	0	<0.3	<0.3	
7/15/[redact]	0	<0.3	<0.3	Date in claim file is 7/22/[redact].
1/23/[redact]	0.272, 0.374	0.3	0.3	
7/31/[redact]	0.203, 0.374, 0.138	<0.3	<0.3	
1/15/[redact]	0	<0.3	<0.3	
7/15/[redact]	0.14	<0.3	<0.3	
1/6/[redact]	0	<0.3	<0.3	
7/19/[redact]	0	<0.3	<0.3	Date in claim file is 7/29/[redact]

7.5.1 Intake Scenarios Considered

Table 25 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 26, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.23 dpm/d on the day of the observed positive sample (reported as 0.3 dpm/d in NOCTS). Additionally, if the positive result is assumed to be caused by an acute exposure occurring midway between the positive and previous sample, the resulting intake is approximately an order of magnitude larger than the 95th percentile chronic coworker assignment over the same period.

Table 25. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]– 1/23/[redact]	16.7 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.18 dpm/d on the date of the positive sample (1/23/[redact]).
Acute	10/19/[redact]	2.1E+04 dpm	Date of intake assumed to be half way between positive sample and prior sample (40 days prior to the positive sample). 95th percentile coworker intake over a 1 year period totals approximately 6E+03 dpm.

7.5.2 Additional Comments

The claimant's urine result from January 23, [redact], had an average of 0.32 and was reported in the claimant's NOCTS bioassay file as 0.3 dpm/1.5 L. One problem with the result is its inconsistency among the discs that should reflect the same sample activity. There were two disc results, one of them less than the MDA (0.272 dpm/1.5 L) and one higher than the MDA (0.374/1.5 L). Similarly, the claimant's urine result from July 31, [redact], had three disc results (0.203 dpm/1.5 L, 0.374 dpm/1.5 L and 0.138 dpm/1.5 L). The first two disc results are similar

to the ones obtained in January 23, [redact]; however, the third disc showed a much lower counting rate. The result from July 31, [redact], was reported as below the MDA. The uncertainties on results near or below the MDA are very high; if the claimant was actually exposed to Am-Cm during [redact], it is feasible they could have been exposed for the entire year.

7.5.3 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample (96 days), the total intake is a factor of 3–5 higher than the 95th percentile intake totaled over 1 year.

7.6 CLAIM #[6]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]/[Redacted]

Table 26 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result was observed on June 3, [redact]; the next sample taken was a few months later and was designated a "resample." The positive sample was an average of a disc measurement above the MDA and a disc measurement below the MDA. An additional sample on December 15, [redact], contained one positive disc result; however, the second disc measurement was negative, so the sample was reported as <0.3. The claimant was also monitored via in vivo at various points from [redact] through [redact]; however, no in vivo result was identified with [redact] when the positive bioassay measurement was observed.

Table 26. Trivalent Urinalysis Results during SEC Period for Claim #[6]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
6/3/[redact]	0.29, 0.44	0.4	0.4	
8/22/[redact]	0	<0.3	<0.3	Sample Designation: "Resample"
12/19/[redact]	0	<0.3	<0.3	
6/17/[redact]	0.08	<0.3	<0.3	
12/5/[redact]	0	<0.3	<0.3	
6/4/[redact]	0	<0.3	<0.3	
1/23/[redact]	0	<0.3	<0.3	Date in claim file is 12/23/[redact].
1/3/[redact]	0	<0.3	<0.3	
12/12/[redact]	-0.056	<0.3	<0.3	
12/26/[redact]	0.139	<0.3	<0.3	
1/2/[redact]	-0.072	<0.3	<0.3	
12/15/[redact]	0.323, -0.07	<0.3	<0.3	
12/1/[redact]	-0.199	<0.3	<0.3	
11/30/[redact]	0.1	<0.3	<0.3	
12/7/[redact]	Missing	Missing	<0.3	

7.6.1 Intake Scenarios Considered

Table 27 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 27, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.15 dpm/d on the day of the observed positive sample (reported as 0.4 dpm/d in NOCTS). In order to reach an Am-241 excretion rate on the day in question of 0.4 dpm/d, a continuous intake rate of 26 dpm/d would be required (higher than the 95th percentile coworker intake of 16.7 dpm/d). Similarly, if the exposure was due to Cm-244, a continuous intake rate of 44 dpm/d would be required (higher than the 95th percentile coworker intake of 19.3 dpm/d).

If the claimant's excretion rate were a result of an acute intake, we do not have information on the date of the intake. The ICRP recommends the use of the middle of the interval between monitoring results as the intake date. Although the claimant had a previous result listed in the coworker database for December 7, [redact], this result was "reported" in the original records as lost in process. This result does not appear in the NOCTS monitoring records provided by the U.S. Department of Energy (DOE). Therefore, it is inappropriate to use this sample to establish a reasonable acute intake date and thus there is insufficient information available to estimate an acute intake.

Table 27. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]–6/3/[redact]	16.7 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.15 dpm/d on the date of the positive sample (6/3/[redact]).

7.6.2 Additional Comments

As can be seen in Table 26, the positive result on June 3, [redact], consisted of both an above MDA measurement (0.44 dpm/d) and a below MDA measurement (0.29 dpm/d). Additionally, it was noted that one other sample had a positive disc result (0.323 dpm/d), but was reported as <0.3 since the other disc measurement was negative.

7.6.3 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample (69 days), the total intake is over a factor of 4 higher than the 95th percentile intake totaled over 1 year.

7.7 CLAIM #[8]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 28 displays the trivalent bioassay data for the claimant during the SEC period. Two positive results were observed on January 15, [redact], and March 8, [redact]; the latter sample was designated a "resample." Both samples consisted of only positive disc results. The claimant was also monitored via in vivo in [redact] and had a positive Am-241 result of 0.15 nCi.

Table 28. Trivalent Urinalysis Results during SEC Period for Claim #[8]

Date	Bioassay Value (dpm/1.5 L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
7/11/[redact]	0	<0.3	<0.3	
1/8/[redact]	0	<0.3	<0.3	
7/15/[redact]	0	<0.3	<0.3	
1/24/[redact]	0.175	<0.3	<0.3	
7/11/[redact]	0	<0.3	<0.3	
1/15/[redact]	0.463, 0.698	0.6	0.6	
3/8/[redact]	0.712, 0.579	0.6	0.6	Sample Designation: "Resample"
5/11/[redact]	0	<0.3	<0.3	
5/17/[redact]	0	<0.3	<0.3	
5/17/[redact]	0	<0.3	<0.3	
7/12/[redact]	0, 0.21	<0.3	<0.3	
7/18/[redact]	0	<0.3	<0.3	

7.7.1 Intake Scenarios Considered

Table 29 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 29, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.2 dpm/d on the day of the observed positive sample (reported as 0.3 dpm/d in NOCTS). The continuous Am-241 intake rate required to reach an excretion rate of 0.6 dpm/d is approximately 51 dpm/d (compared to the 95th percentile coworker assignment of 16.7 dpm/d). Similarly, if the exposure was to curium, the observed excretion rate would correspond to a continuous intake rate of 53 dpm/d (compared to the 95th percentile coworker assignment of 19.3 dpm/d).

Additionally, if the positive result is assumed to be caused by an acute exposure occurring midway between the positive and previous sample, the resulting intake is approximately an order of magnitude larger than the 95th percentile chronic coworker assignment over the same period.

Table 29. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]–1/15/[redact]	16.7 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.2 dpm/d on the date of the positive sample (1/15/[redact]).
Acute	7/21/[redact]	5.45E+04 dpm	Date of intake assumed to be half way between positive sample and prior sample (178 days prior to the positive sample). 95th percentile coworker intake over a 1 year period totals approximately 6E+03 dpm.

7.7.2 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample (178 days), the total intake is nearly an order of magnitude higher than the 95th percentile intake totaled over 1 year.

7.8 CLAIM #[9]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]

Table 30 displays the trivalent bioassay data for the claimant during the SEC period, the claimant was also monitored through in-vivo counting in [redact]–[redact], [redact], and [redact]. The only positive result was observed on December 28, [redact]; this sample could not be located in the NOCTS claimant files. The sample contained three disc measurements that were positive and one disc measurement that was zero. The claimant was monitored via in vivo multiple times from [redact] up through [redact] (including [redact]); however, all results were less than the MDA.

Table 30. Trivalent Urinalysis Results during SEC Period for Claim #[9]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
3/16/[redact]	0.18, 0.288, 0.015	<0.3	<0.3	
12/28/[redact]	0.771, 0.925, 0, 0.511	0.8	Missing	Only a plutonium sample exists on this date in the claim file.
12/5/[redact]	0, 0.079	<0.3	<0.3	

7.8.1 Intake Scenarios Considered

Table 31 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 31, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.23 dpm/d on the day of the observed positive sample. The required continuous intake rate of Am-241 to reach 0.8 dpm/d on 12/28/[redact] would be 58 dpm/d (compared to the 95th percentile coworker assignment of 16.7 dpm/d). Similarly, if the exposure was due to curium, then the required continuous intake rate would be 61 dpm/d (compared to the 95th percentile coworker assignment of 19.3 dpm/d).

Additionally, if the positive result is assumed to be caused by an acute exposure occurring midway between the positive and previous samples, the resulting intake is approximately an order of magnitude larger than the 95th percentile chronic coworker assignment for a full year of exposure.

Table 31. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]– 12/28/[redact]	0.23 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.23 dpm/d on the date of the positive sample (12/28/[redact]).
Acute	8/6/[redact]	6.5E+04 dpm	Date of intake assumed to be halfway between positive sample and prior sample (144 days prior to the positive sample). 95th percentile coworker intake over a 1 year period totals approximately 6E+03 dpm.

7.8.2 Additional Comments

As can be seen in Table 30, the positive result on December 28, [redact], had highly variable individual disc measurements, which ranged from zero to 0.925 dpm/d. Three of the four disc measurements were well above the MDA (0.511, 0.711, 0.925 dpm/d), while the fourth was zero.

7.8.3 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. If an acute exposure is assumed to have occurred at the midpoint between the positive sample and the previous sample (144 days), the total intake is over an order of magnitude higher than the 95th percentile intake totaled over 1 year.

7.9 CLAIM #[10]

Employment Period: [Redacted]–[Redacted]
Job Title: [Redacted]/[Redacted]

Table 32 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result in the coworker database was observed on January 11, [redact]; the next sample was taken nearly a year and a half later. The positive sample consisted of three disc results that were all above the MDA of 0.3. In the NOCTS claim file, the positive result of "0.4 dpm/d" was taken on August 30, [redact]. The claimant also had several in-vivo monitoring results from [redact] to [redact]. All measured results were below the MDA, although no in-vivo monitoring results were available in [redact].

Table 32. Trivalent Urinalysis Results during SEC Period for Claim #[10]

Date	Bioassay Value (dpm/1.5L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
1/11/[redact]	0.002	<0.3	Missing	No bioassay results were identified in [redact] in claim file.
1/11/[redact]	0.353, 0.506, 0.34	0.4	<0.3	
8/30/[redact]	Missing	Missing	0.4	
6/28/[redact]	0	<0.3	<0.3	
3/8/[redact]	Missing	Missing	<0.3	
3/4/[redact]	0.002	<0.3	<0.3	

7.9.1 Intake Scenarios Considered

Table 33 summarizes the modeled intakes based on the single observed positive urinalysis sample. As seen in Table 33, the predicted excretion result based on the application of the 95th percentile Am-241 coworker intake rate is approximately 0.24 dpm/d on the day of the observed positive sample (reported as 0.4 dpm/d in NOCTS). The Am-241 continuous intake rate required to obtain the observed positive result in 1979 would by approximately 28 dpm/d (compared to the 95th percentile coworker model intake rate of 16.7 dpm/d). If the exposure were attributed to curium, a continuous intake rate of 0.29 dpm/d would be required (higher than the 95th percentile coworker intake rate of 19.3 dpm/d).

Table 33. Summary of Calculated Intakes and Intake Comparison

Type of Intake	Date of Intake or Duration of Intake	Total Intake (dpm) or Intake Rate (dpm/d)	Additional Comments
Coworker Chronic	1/1/[redact]– 1/11/[redact]	0.24 dpm/d	Intake rate based on 95th percentile coworker Am-241 intake rate (ORAUT 2013). The predicted excretion rate based on the coworker intake rate would be 0.24 dpm/d on the date of the positive sample (1/11/[redact]).

7.9.2 Conclusion

Application of the 95th percentile of the coworker model as a chronic exposure beginning in [redact] would result in a lower predicted excretion rate than the positive sample observed in the claimant's monitoring records. The continuous intake rate required to obtain the observed positive result exceeds the 95th percentile coworker intake for americium and curium.

7.10 CLAIM #[12]

Employment Period: [Redacted]–[Redacted], [Redacted]–[Redacted]
Job Title: [Redacted]

Table 34 displays the trivalent bioassay data for the claimant during the SEC period. The only positive result was observed on April 29, [redact], with additional samples taken in subsequent days. The sample contained one disc measurement that was positive and one disc measurement that was below the MDA. The claimant was involved in an Am-241 intake incident that occurred during a maintenance operation. In addition to the bioassay results shown, fecal and in-vivo monitoring were also conducted. These monitoring results are presented and discussed under "Intake Scenarios Considered."

Table 34. Trivalent Urinalysis Results during SEC Period for Claim #[12]

Date	Bioassay Value (dpm/1.5 L)			Additional Comments
	Database Result(s)	Logbook Report Value	NOCTS Result	
4/29/[redact]	0.679, 0.223	0.4	0.4	Sample Designation: "Special"
5/1/[redact]	0.164	<0.3	<0.3	Sample Designation: "Follow-up"
5/2/[redact]	0, 0.552, 0, 0.161	<0.3	<0.3	Sample Designation: "Follow-up"
5/2/[redact]	0, 0, 0.147, 1.92	<0.3	<0.3	The average of the disc results is 0.52 dpm/d; however, the logbook and NOCTS files report the value as <0.3. The coworker database uses the average value. It appears that the 1.92 dpm/d disc result was crossed out in the original hardcopy record.
5/5/[redact]	0.223, 0.343, 0.211, 0.204	<0.3	<0.3	Sample Designation: "Follow-up"

7.10.1 Intake Scenarios Considered

The in-vivo and fecal monitoring results are presented in Tables 35 and 36, respectively. Based on these results, it appears that the available bioassay measurements do not adequately reflect the actual intake experienced by the claimant. Using the five positive in-vivo results and the unweighted least squares method, the calculated acute intake is approximately 16 nCi (3.6E+04 dpm). This calculated acute intake is higher than the annual Am-241 assignment at the 95th percentile (6E+03 dpm per year).

Table 35. In-Vivo Monitoring Results for Claim #[redact]

Date	Days Post Intake	Measured Contaminant	Results (nCi)
4/30/[redact]	1	Am-241	1.21
		Cm-244	51
		Pu-239	97
		Pu-238	41
5/5/[redact]	6	Am-241	0.53
		Cm-244, Pu-239, Pu-238	<MDA
10/21/[redact]	175	Am-241	0.29
		Cm-244, Pu-239, Pu-238	<MDA
1/26/[redact]	272	Am-241	<0.16
5/19/[redact]	385	Am-241	<0.19
9/2/[redact]	491	Am-241	0.17
5/16/[redact]	747	Am-241	0.17

Table 36. Fecal Sampling Results for Claim #[redact]

Date	Activity (nCi)	Mass	Daily Excretion[a] (nCi/d)
5/1/[redact]	0.4	54	1.1
5/3/[redact]	2.3	140	2.4
5/4/[redact]	<0.2	36	–
5/5/[redact]	<0.3	36	–

a ICRP Publication 89 (2002) assumes the daily mass of fecal excretion for a reference male is 150 grams.

The fecal results shown in Table 36 carry a lot of uncertainty related to the amount excreted per day and the daily function of the intestinal tract. This may account for the increase in the activity excreted in feces from May 1, [redact], to May 4, [redact]. Despite these uncertainties, it can be concluded that a significant activity of Am-241 was inhaled by the worker. Another very important conclusion from this case is that the urine activity excreted did not reflect the intake of this worker. The reported result would predict an intake of 2.3E+02 dpm, much lower than the one predicted by the available chest count. It must also be noted that one of the two disc results used to indicate the intake of the worker was below the MDA.

7.10.2 Conclusion

Based on the in-vivo and fecal sampling for the claimant, as well as the documented intake of Am-241 on April 29, [redact], it is evident that the associated urinalysis measurements did not adequately identify the significant acute intake experienced by the worker. Furthermore, the 95th percentile coworker intake rate would underestimate the observed excretion rate if continuous exposure is assumed beginning in [redact] and extending through the date of the positive sample.

7.10.3 Intake Analysis Findings

Finding 17: Uncertainties observed in the urine in-vitro methodology are very high for the sampled claimants, making accurate intake assessments particularly difficult. This is evident in multiple instances where differences in disc results for the same sample are significant. Additionally, the reported urinalysis activity was very low for one claimant who had a confirmed high intake based on fecal and in vivo measurements. This may be due to problems in the urine bioassay method.

Finding 18: The 95th percentile daily intake rates for Am-241 and Cm-244 in the period 1973–1994 predict excretion rates that are below the DL for the first 10 years of continuous exposure. Any worker that had a positive excretion rate during the first 10 years of exposure without an indication of a specific incident occurring in a small interval of time before the sampling will be misrepresented by the 95th percentile coworker model.

8.0 EVALUATION OF THE COMPLETENESS OF THE TRIVALENT ACTINIDE BIOASSAY DATABASE

In order to assess the completeness of the compiled trivalent actinide bioassay data, SC&A analyzed the job title (Section 8.1) and work location (Section 8.2) included with each result. In addition, SC&A examined the NOCTS files for any claimant contained in the database. This analysis included verifying the job title classification as well as comparing the monitoring results provided by DOE to the compiled results used in the coworker model (Section 8.3). The database itself is located at: [O:\Savannah River Site SEC\SRS databases for Coworker Models 021713\Am Final Compiled_SRS WHC_06302011r2_OPOS analysis R10 CTW NCW unkstrata %s.xlsx]. For this analysis, SC&A only considered records taken from October 1972 through December 1989.

Observation 1: SC&A noted that many results were excluded from the OPOS analysis for various reasons including no apparent date to the sample, sample was marked lost in process, or chelation was involved. SC&A identified 52 samples that were excluded, mainly based on a missing date, which likely could still be used in the coworker model since the date of the report can be used to accurately place the sample in a given year.

8.1 ANALYSIS OF MONITORED JOB TITLES

Job titles were originally assessed in RPRT-0055 by two main methods, as described in Section 3.2 of that report. Namely, occupations were assigned based on either a payroll ID prefix or using a specific employee's "SRS Work History Card." SC&A was not able to review the latter source of employment information, as the original directory containing that information is not available. However, SC&A was able to compare job classification information involving claimants which is discussed in Section 8.3. Nonetheless, SC&A evaluated the assigned job titles in the database population to assess which occupations were selected for monitoring. The dataset contains over 50 distinct job titles. In order to simplify the analysis, SC&A combined several job types into nine individual categories shown as "SC&A Condensed Job Title" in column 1 of Table 37. The second column of Table 37 displays the number of bioassay results associated with each job category, and also the percentage of total samples for each occupation. For clarification, column 3 indicates which unique job titles were associated with the larger category. For example, one can see that the "Technician/Operator" category contains 3,076 total samples covering 7 individual job titles, 1,698 of which are attributed to the job title of "Technical Assistant."

Not surprisingly, the most samples were attributed to the "Technician/Operator" category, followed by "Trade Workers" and "Scientists/Engineers." It is logical that these types of occupations would have the higher exposure potential and indicates that the sampling protocol was not homogeneous. This is reinforced by the fact that administrative-type positions composed only about 1% of the available samples.

Table 37. Overview of Job Titles by Sample Present in Am/Cm/Cf Database during the SEC Period

SC&A Condensed Job Title	Total Samples (% of Total)	Database Job Titles Included in Condensed Category (Number of Samples)
Technician/Operator	3,076 (36.26%)	Technical Assistant (1,698), Operator (1,111), Technician (238), Power Operator (15), Lab (7), Lab analyst (4), Heavy Water Operator (3)
Trade Worker	1,421 (16.75%)	Mechanic (940), Electrician (266), Laborer (65), Pipefitter (37), Sheetmetal Worker (35), Heavy Equipment Operator (22), CTW (15), Painter (15), Boilermaker (7), Maintenance (7), Rigger (5), Carpenter (4), Millwright (2), Ironworker (1)
Scientist/Engineer	1,301 (15.34%)	Engineer (569), Chemist (535), Research Associate (66), Metallurgist (56), Physicist (44), Ceramist (13), Geologist (12), Biologist (4), Mathematician (1)
Supervisor/Foreman	1,083 (12.77%)	Supervisor (655), Foreman (407), Laboratory Supv (11), Manager (9), Shift Supervisor (1)
Unknown	662 (7.80%)	"Unk" (265), Roll 2 (223), Roll 1 (174), Blank
Health Physics	586 (6.91%)	Health Physics (586)
Project Assistant	132 (1.56%)	Project Assistant (113), Assistant (19)
Other	131 (1.54%)	Co-op (28), Glass Blower (22), Patrolman (22), Driver (17), Specialist (13), Draftsman (9), Fellow (7), Computer (5), Illustrator (5), Conductor (1), Librarian (1), Photographer (1)
Administrative	91 (1.07%)	Clerical (90), Accountant (1)

Table 38 further analyzes the assigned job titles by examining the number of individual workers monitored, as opposed to the total number of samples. Similar to Table 37, the "Technician/ Operator" category made up the largest portion of monitored workers and also had the second highest average number of samples per worker. It is also worth noting that administrative-type positions had the lowest average number of samples per worker.

Table 38. Overview of Job Titles by Worker in the Am/Cm/Cf Database during the SEC Period

SC&A Condensed Job Title	Number of Workers (% of Total)	Average Number of Samples per Worker
Technician/Operator	547 (28.76%)	5.62
Scientist/Engineer	308 (16.19%)	4.22
Trades Worker	306 (16.09%)	4.64
Supervisor/Foreman	263 (13.83%)	4.12
Unknown	263 (13.83%)	2.52
Health Physics	72 (3.79%)	8.14
Other	67 (3.52%)	1.96
Administrative	47 (2.47%)	1.94
Project Assistant	29 (1.52%)	4.55

Observation 2: Based on the job title analysis, it is apparent that the monitored worker population is not homogeneous but biased towards job types that are more likely to be exposed, such as lab technicians/technical assistants and operators.

8.2 ANALYSIS OF ASSOCIATED WORK AREAS

In addition to job title, the work areas associated with each individual sample were examined to establish the focus of the monitoring program. Similar to the job title analysis, SC&A condensed the 32 distinct locations contained in the database to 11 main work areas, as shown in Table 39. By far, the most common area sampled was the "Laboratory/Technology Areas," which comprised nearly three quarters of the dataset. The subset of this condensed area is focused on Building 773 (also known as the Savannah River Laboratory), where the majority of exposure potential to trivalent actinides is likely to occur. The Separations Facilities (F and H area) are next highest. The "Central Shops" were rarely reported as the work location. However, as noted in the previous section, "Trades Workers" comprised a significant portion of the monitored population, so it is likely this is simply an indication of where the employee was actually working versus where they were commonly "badged."[3]

Table 39. Overview of Work Areas by Samples Present in Am/Cm/Cf Database during the SEC Period

SC&A Condensed Work Areas	Total Samples (% of Total)	Database Work Areas Included in Condensed Category (Number of Samples)
Laboratory/Technology Areas	6,196 (73.04%)	773 (4447), A (1287), Tech (225), SRL (120), 773-A (49), 735 (37), 735-A (10), A-773 (10), 793 (8), 7, (2), 703-A (1)
F Area	1,283 (15.12%)	F (1282), F-NF (1)
H Area	276 (3.25%)	H (276)
Reactors	253 (2.98%)	P (175), C (57), K (19), L (2)
Unknown	222 (2.62%)	Blank (217), UNK (5)
CMX/TNX	93 (1.10%)	CMX (68), TNX (25)
M Area	55 (0.65%)	M (55)
D Area	44 (0.52%)	D (44)
G Areas	33 (0.39%)	G (33)
Other	18 (0.21%)	S (9), NF (6), RR (2), BG(1)
Central Shops	10 (0.12%)	CS (8), Crs (1), C/S (1)

Observation 3: The monitoring program is heavily focused on Building 773 (the Savannah River Laboratory) where research campaigns were conducted using trivalent actinides and the highest potential for intake would likely occur.

8.3 REVIEW OF CLAIMANT FILES CONTAINED IN THE COWORKER DATABASE

Among the monitored worker population, 152 claimants were identified that comprised over 1,500 of the nearly 8,500 samples (~18%). To establish consistency and completeness of the coworker database, the monitoring records provided by DOE for each claimant were compared. As noted in Table 40, discrepancies between the database and claimant records fell into three categories:

[3] It has been observed that occupations such as maintenance workers often received their external dosimetry badges out of the central shops, but would then be assigned to work in various locations at the SRS as needed.

(1) Records found in DOE claimant files that were not found in the coworker database.

(2) Records found in the coworker database, but not found in the individual claimant files.

(3) Records that displayed the same date, but a different year (an example would be the database showing 11/1/1981 and the DOE claimant file showing (11/1/1982).

This third category is important, since the OPOS statistic and subsequent comparison of occupational strata are generally based on yearly intervals; therefore, the correct assignment of samples to a given year is critical. As can be seen in Table 40, neither source of monitoring records could be considered strictly complete, since each contained records that its counterpart did not. Logically, one would ask the question of what effect the additional records observed in the claimant files would have on the coworker model. With the exception of 5 of the 106 samples, all of the additional claimant records were below the DL of 0.3 dpm/1.5 L (~ 95% <MDA). Conversely, 73 of the 84 samples contained in the coworker database that were not found in the claimant records were below the DL (~87% <MDA). Observed instances of a discrepancy in the year of a sample (category 3) were approximately 1.9%, which is comparable to the 1% critical error rate described in Section 3.1 of RPRT-0055. It should also be noted that SC&A identified 80 samples that were taken during or in the months following administration of a chelating agent. Per the methodology outlined in Section 3.1 of RPRT-0055, these samples should be removed from the coworker dataset.

Table 40. Summary of Observed Discrepancies between Claimant Monitoring Records and Trivalent Coworker Database

Category #	Description	Number of Observations	Percentage of Total Claimant Records
1	Additional Records in Claim File	106	7.0%
2	Additional Records in Coworker Database	84	5.6%
3	Discrepancies in the Year of the Sample	29	1.9%

In addition to the comparison with DOE monitoring records, the claimant files were used to compare the job types assigned in NOCTS and described in the claimant's associated CATI reports (Computer Assisted Telephone Interview) to the job assigned in the coworker database. In particular, job designations were examined to establish if the worker and associated sample were correctly assigned to the "CTW" or "NCW" categories for the purpose of strata comparison. In total, 21 of the 152 (~14%) claimants showed some discrepancy between the coworker database occupation assignment and what was contained in the individual claim file. The specific cases and subsequent investigatory notes are shown in Table 41. Of the 21 observed cases:

- 14 likely merit a change in job type designation (~9% of all monitored claimants)
- 3 do not merit a change in job designation based on additional information in the claim file
- 4 were inconclusive when examining the claim files to establish job category

As noted previously, SC&A did not have access to the "SRS Work History Cards" that were used to establish a given occupation for a worker in a given time period, so we cannot comment

on the veracity of that information. However, it is understood that in some of the observed cases (particularly the inconclusive cases), the discrepancy could be a product of the fact that often occupational information in the claim file is not temporally delineated. Therefore, it may be that a claimant began work at SRS in a "CTW" type job and then moved to an "NCW" occupation and vice versa. Nevertheless, it would be beneficial for NIOSH to characterize the accuracy of the information provided in the "SRS Work History Cards" and, to the extent feasible, perform an extensive quality assurance study to verify that workers are correctly assigned to the given strata.

Table 41. Discrepancies Identified between Coworker Database Occupation Assignment and Claimant NOCTS/CATI Job Descriptions

NIOSH Claim ID	# Samples	CTW	NIOSH Occupation	NOCTS Job Title	CATI Job Title	Additional Comments/ Recommended Status Change
[redact]	19	N	Roll 1	Mechanic and Foreman	[redact]	From CATI: "[redact] employees in the E&I Mechanics Group." Recommend change to CTW: "Y"
[redact]	1	Unk	Roll 2	Lab Technician	[redact]	Recommend change to CTW: "N"
[redact]	64	N	Health Physics	Construction	[redact]	CATI report indicates construction work only occurred in the pre-1972 timeframe. Recommend no change.
[redact]	5	N	Project Assistant	Machinist	[redact]	From CATI: "Description of Routine Duties: [redact]." Recommend change to CTW: "Y"
[redact]	4	N	Foreman	Maintenance Worker	[redact]	From CATI: "Description of Routine Duties: [redact]." Recommend change to CTW: "Y"
[redact]	3	N	Project Assistant	Instrument Mechanic, Project Assistant	[redact]	From CATI: "Description of Routine Duties: [redact]Unclear when claimant moved to reactor operation. DOL form EE-3 lists "E+I [redact]" as Position Title and Work Performed. Job designation discrepancy is inconclusive.
[redact]	3	N	Foreman	Mechanic, Supervisor	[redact]	From CATI: "Description of Routine Duties: [redact]." Recommend change to CTW: "Y"
[redact]	1	N	Technician	Lab Tech, Electrician/ Instrument Mechanic	[redact]	CATI report does not indicate when job types may have changed. DOL file indicates claimant was transferred from [redact] to the E&I department as a [redact] but not when it occurred. Job designation discrepancy is inconclusive.
[redact]	2	N	Project Assistant	Area Maintenance Mechanic	[redact]	From CATI: "[redact]." Actinide samples taken in [redact] and [redact]. Recommend no change.
[redact]	5	N	Foreman	E&I Works Engineering	[redact]	From CATI: "Duties: [redact]." Recommend change to CTW: "Y"
[redact]	7	N	Roll 1	Maintenance Mechanic	[redact]	From CATI: "[redact]." Actinide samples cover period when claimant was a [redact]. Recommend change to CTW: "Y"
[redact]	17	N	Technical Assistant	Construction, Lab Tech	Unavailable	DOL case files do not specify when jobs were changed; however, it does indicate the claimant started in [redact] before being hired by Du Pont. Recommend no change.

Table 41. Discrepancies Identified between Coworker Database Occupation Assignment and Claimant NOCTS/CATI Job Descriptions

NIOSH Claim ID	# Samples	CTW	NIOSH Occupation	NOCTS Job Title	CATI Job Title	Additional Comments/ Recommended Status Change
[redact]	1	N	Foreman	Unavailable	[redact]	From CATI: "[redact]." Recommend change to CTW: "Y"
[redact]	2	N	Foreman	Maintenance Mechanic	[redact]	From CATI: "[redact]." No mention of being a foreman found in CATI report. Recommend change to CTW: "Y"
[redact]	4	N	Project Assistant	Welder	[redact]	From CATI: "Duties: [redact]." Recommend change to CTW: "Y"
[redact]	8	N	Foreman	Machinist, Later Supervisor	[redact]	From CATI: "[redact]." Recommend change to CTW: "Y"
[redact]	2	Y	Electrician	Separations Operator	[redact]	DOL case file indicates "[redact]" as the work category for this claimant. Recommend change to CTW: "N"
[redact]	6	Y	Glass Blower	Scientific Glass Blower	[redact]	Unclear whether this occupation should be included with construction trades workers. Recommend change to CTW: "N"
[redact]	2	N	Operator	Laborer, Lab Tech, Operator, Mechanic	Unavailable	DOL lists occupations as: [redact], but does not delineate by period. Job Designation discrepancy is inconclusive.
[redact]	2	N	Project Assistant	E&I Mechanic	Unavailable	From DOL initial case: "[redact]." Recommend change to CTW: "Y"
[redact]	6	N	Operator	Laborer, General Service Operator	[redact]	CATI report lists "unknown" for routine duties. DOL initial case lists the following job titles: [redact]): [redact]: [redact]: [redact]: [redact] Job Designation discrepancy is inconclusive.

Observation 4: When comparing the coworker database and individual claimant records, neither source appears to be complete. However, the additional records found in the claimant files had less positive results than the additional records found in the coworker database. Therefore, one can conclude that the samples missing from the coworker database do not adversely affect the formulation of a coworker model.

Observation 5: Approximately 1.9% of the claimant samples reviewed showed discrepancies in the year of the sample. While this would be considered a "critical error" in the transcription of the data, it is very comparable to the critical error rate of 1% described by NIOSH in Section 3.1 of RPRT-0055.

Observation 6: SC&A observed 80 claimant samples that were taken during or in the subsequent months following chelation treatment. These samples should be removed from the coworker dataset.

Observation 7: SC&A noted that about 9% of the monitored claimants showed discrepancies between the job classifications displayed in the coworker database versus available NIOSH/OCAS Claims Tracking System (NOCTS) records. It would be beneficial to perform a detailed characterization of how job titles have been established in the coworker database. To the extent feasible, an adequate quality assurance activity should be undertaken to ensure that monitored workers are correctly placed in the CTW and NCW strata.

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ATTACHMENT A: COMPARISON OF NCW AND CTW DISTRIBUTIONS AND GEOMETRIC MEANS, 1966 TO 1989

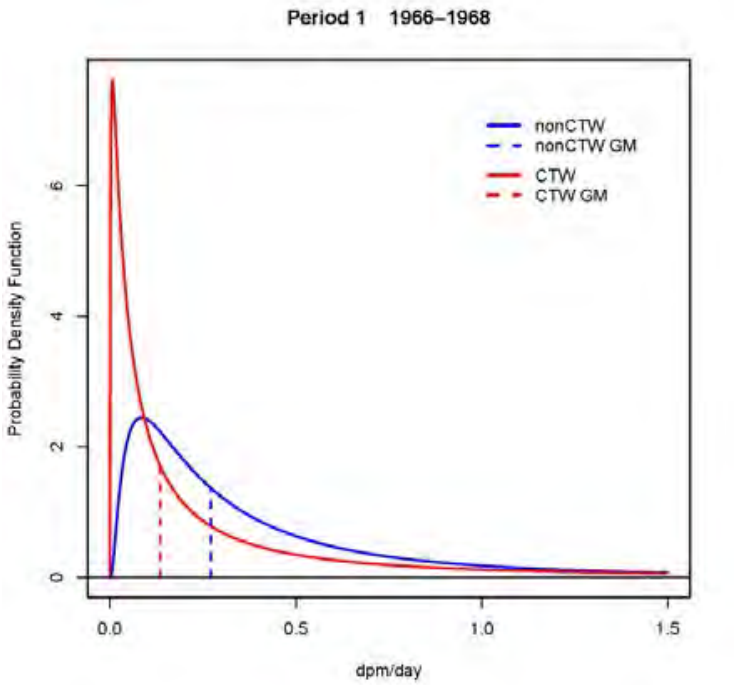

Figure A-1. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1966–1968

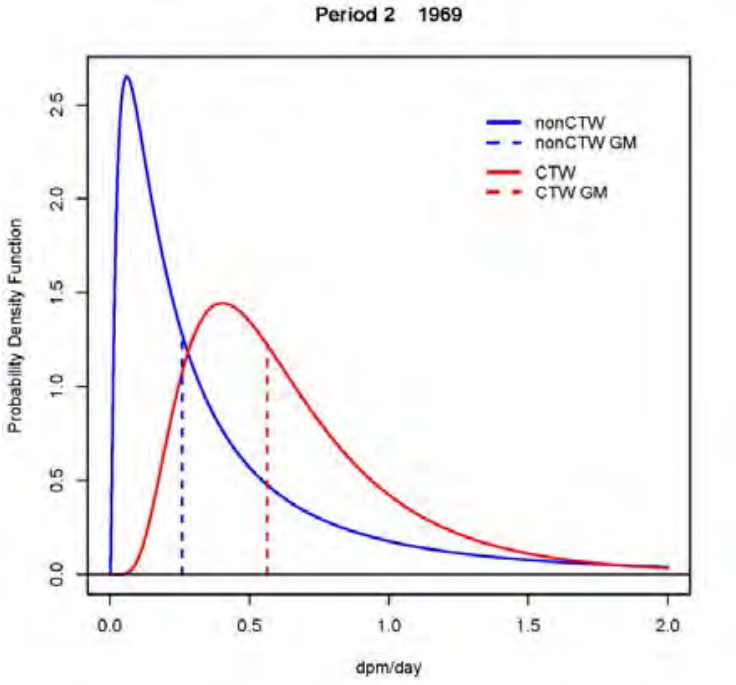

Figure A-2. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1969

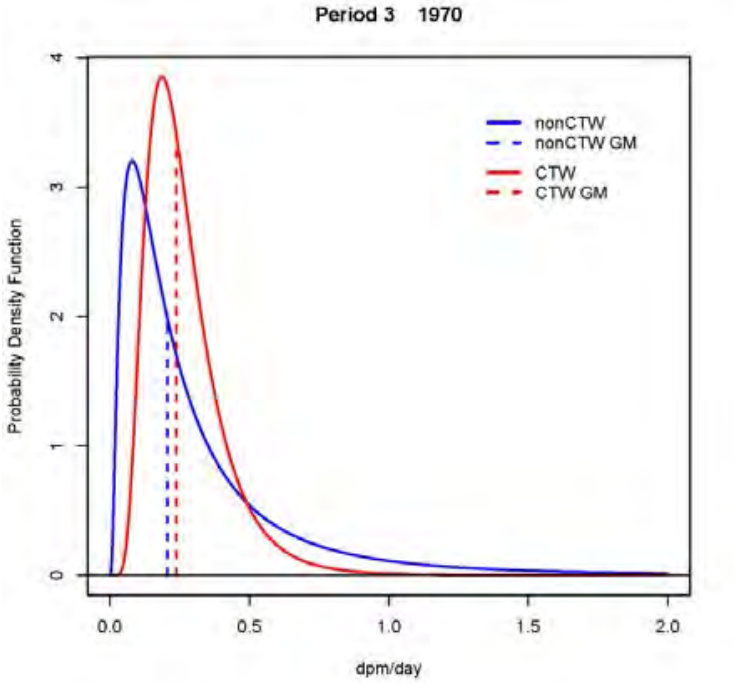

Figure A-3. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1970

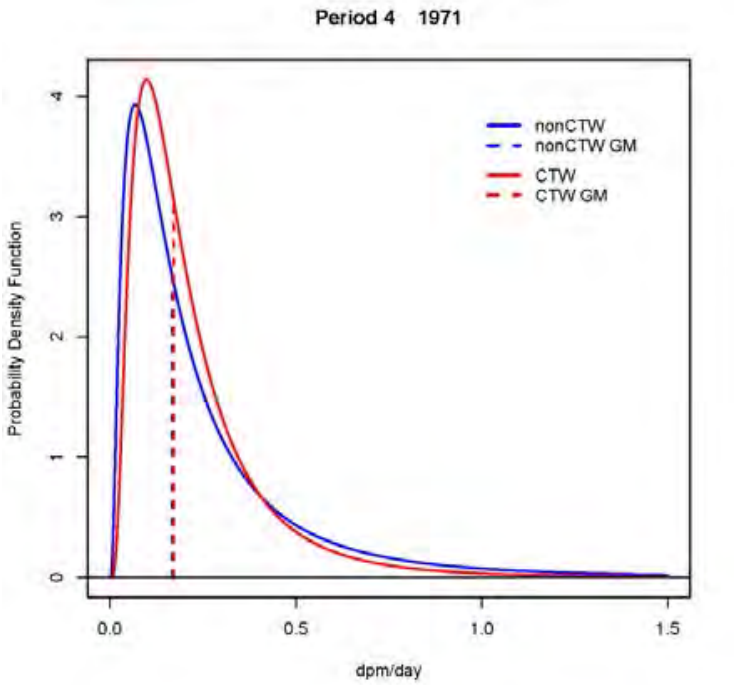

Figure A-4. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1971

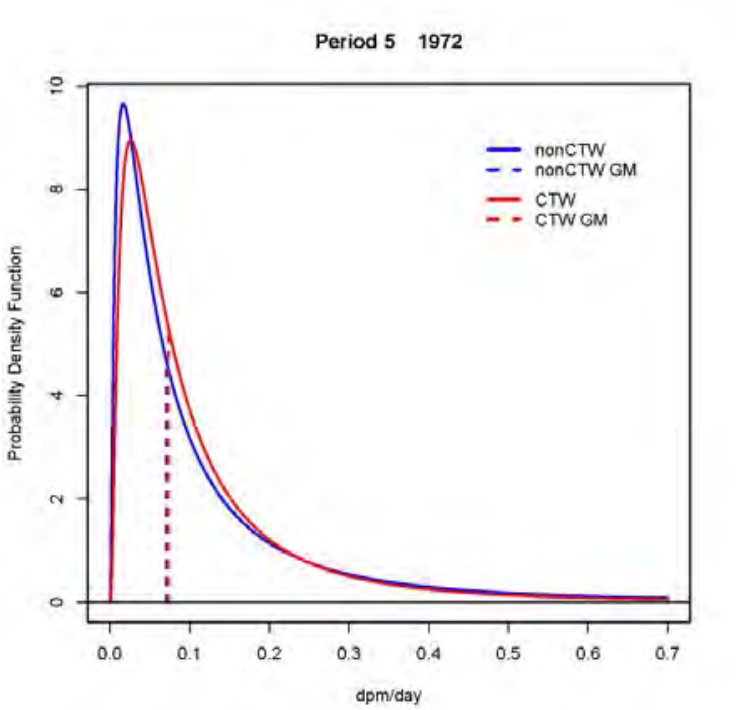

Figure A-5. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1972

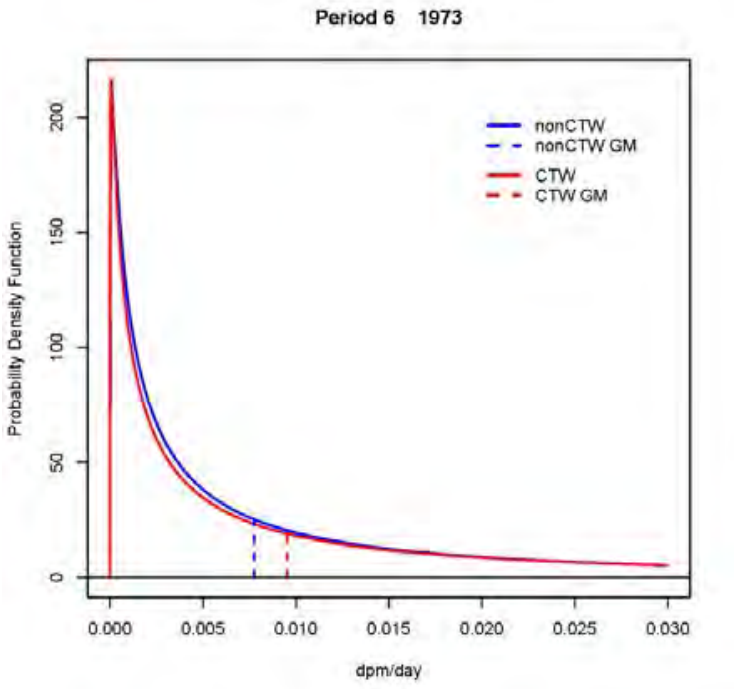

Figure A-6. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1973

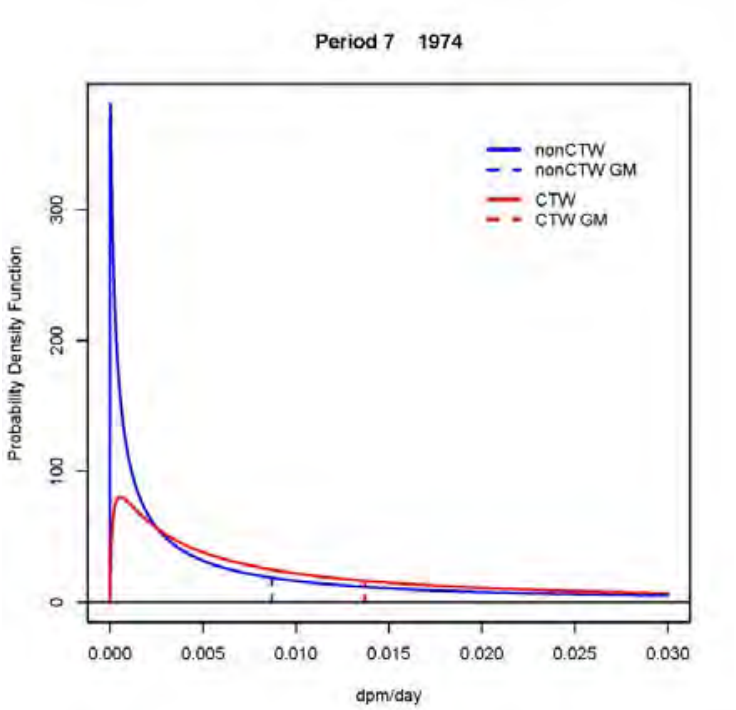

Figure A-7. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1974

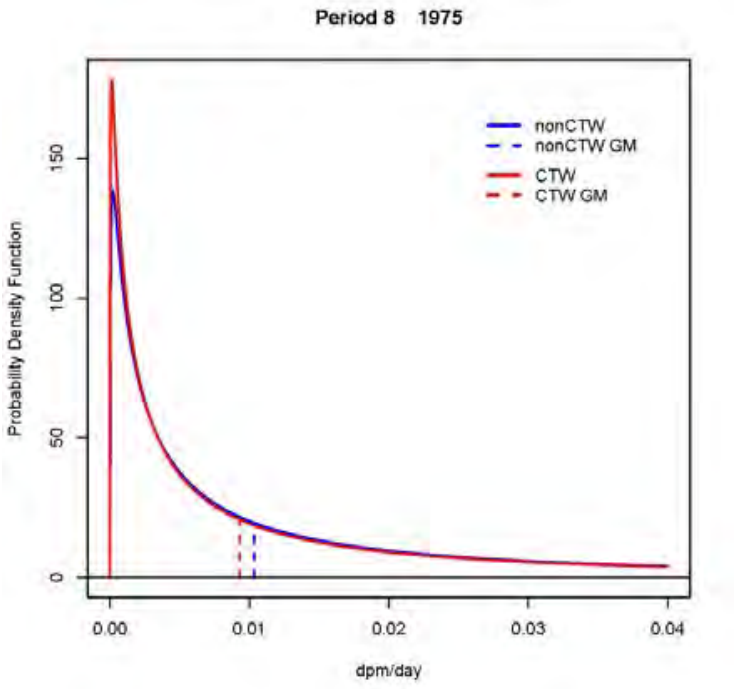

Figure A-8. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1975

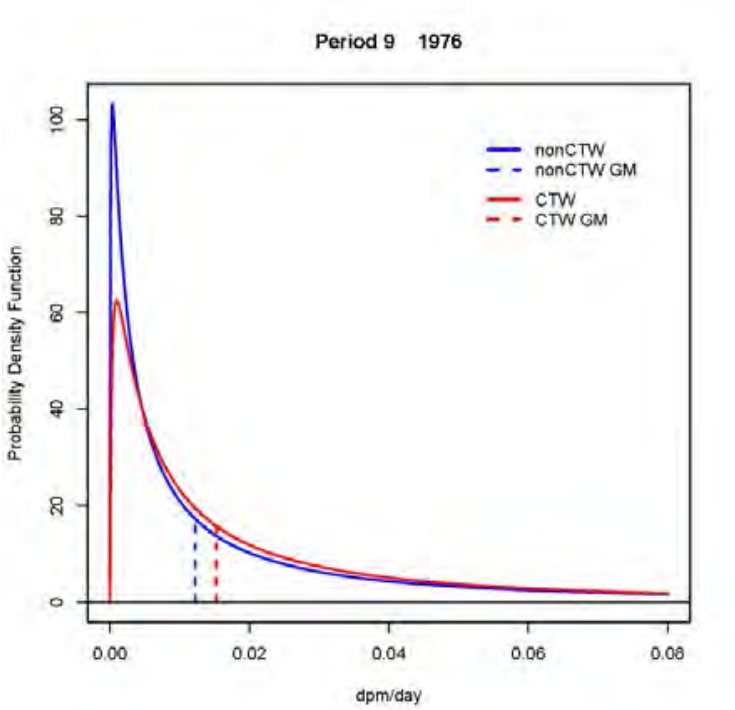

Figure A-9. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1976

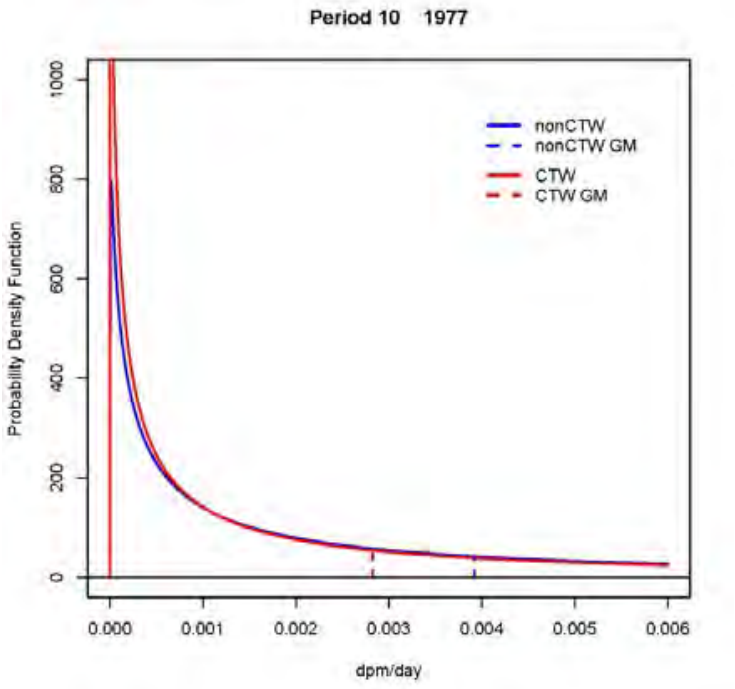

Figure A-10. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1977

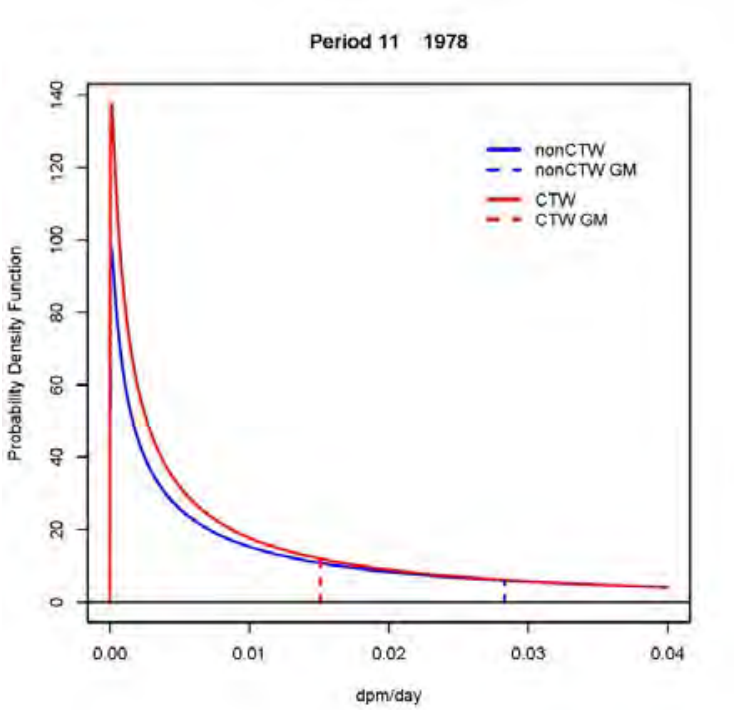

Figure A-11. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1978

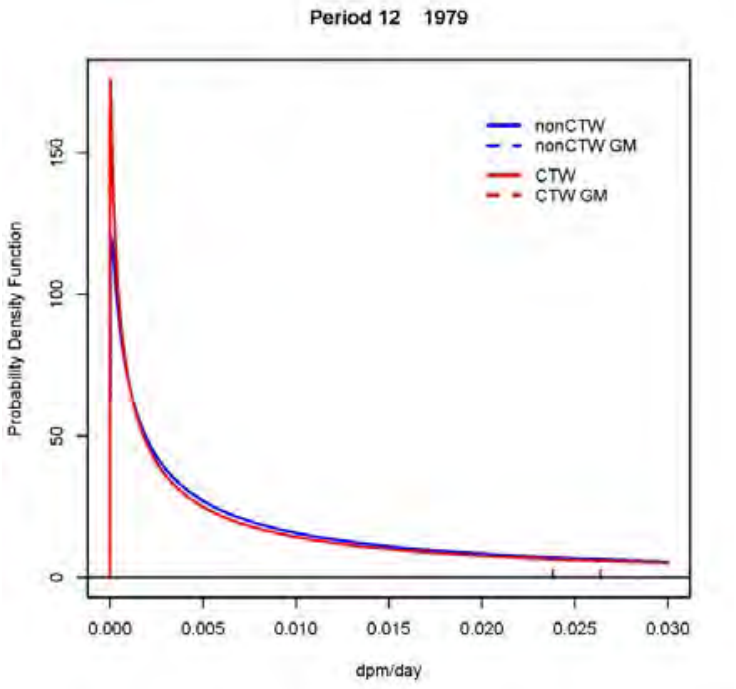

Figure A-12. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1979

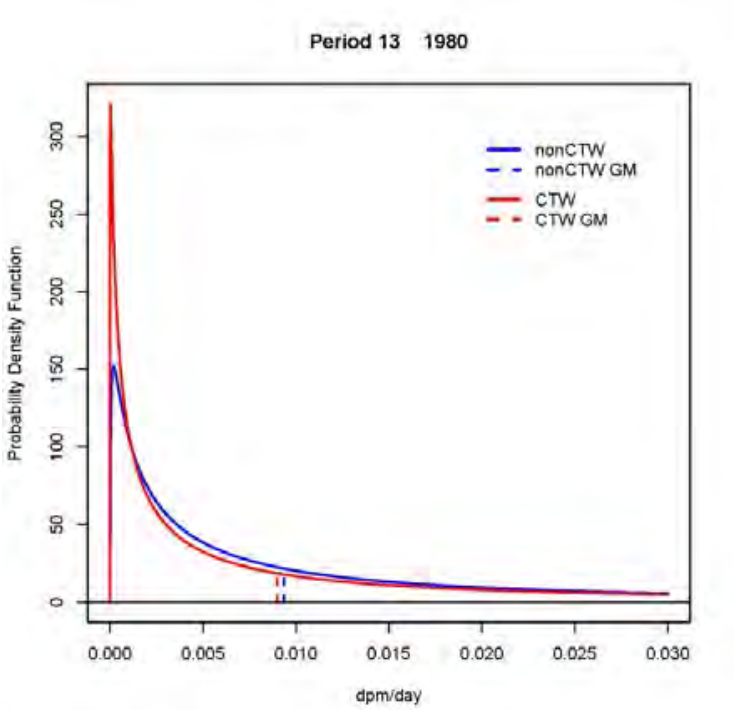

Figure A-13. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1980

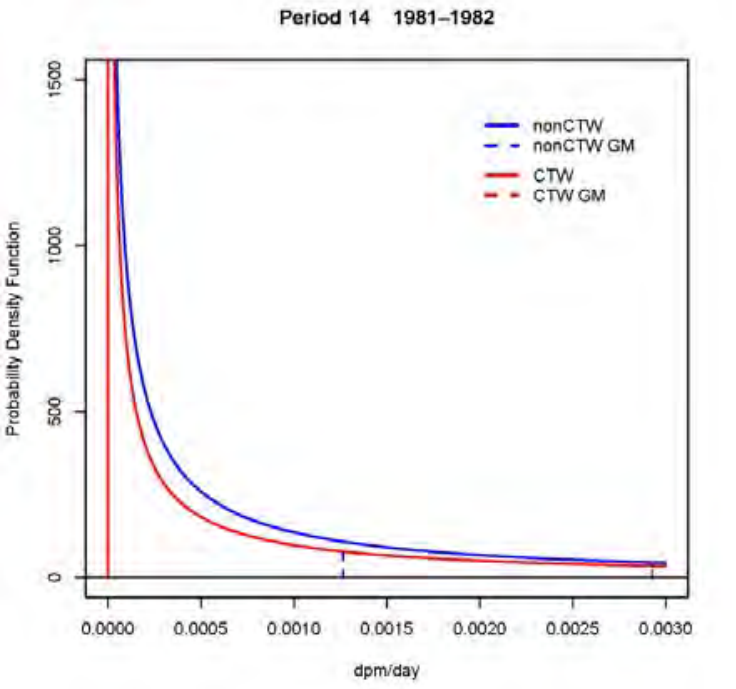

Figure A-14. Comparison of NCW and CTW Distributions and Geometric Mean (GM), 1981–1982

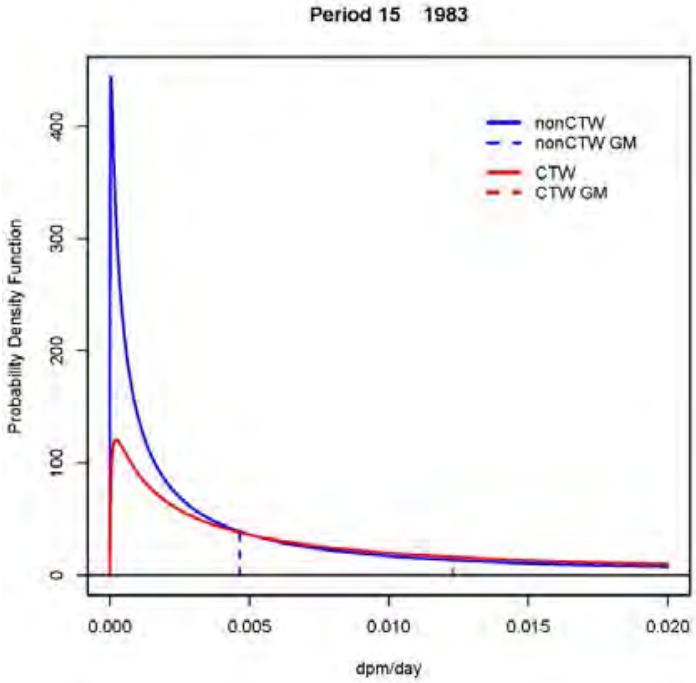

Figure A-15. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1983

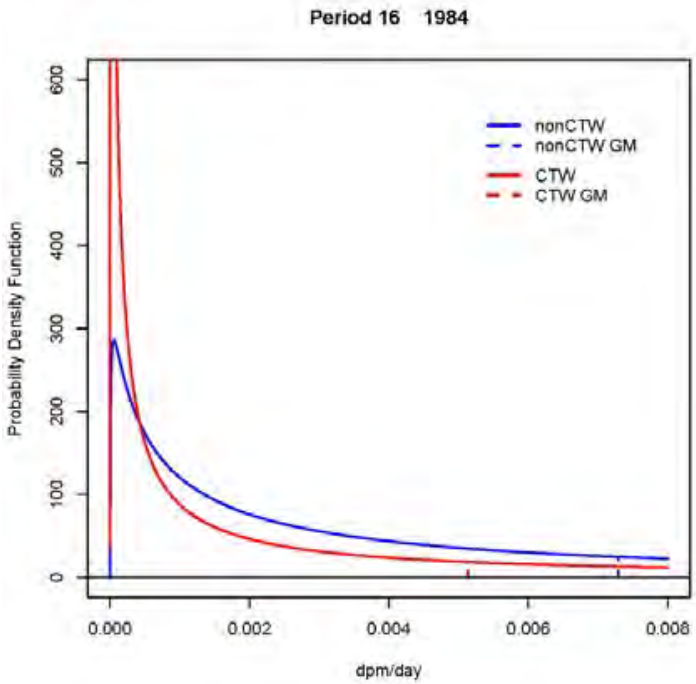

Figure A-16. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1984

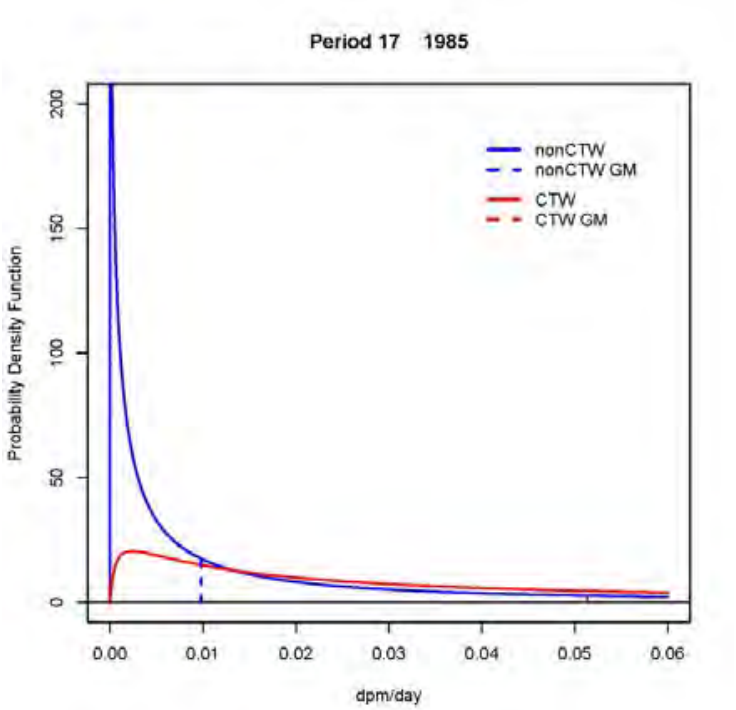

Figure A-17. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1985

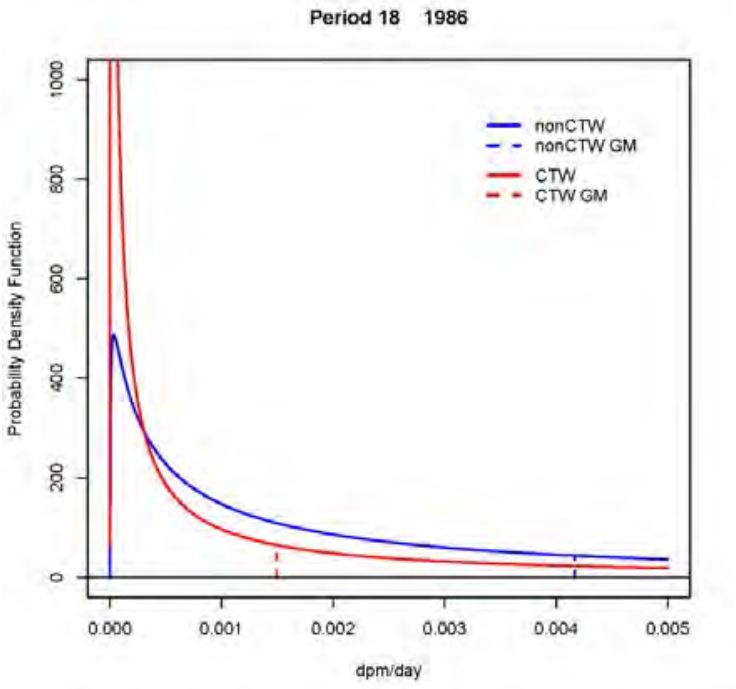

Figure A-18. Comparison of NCW and CTW Distributions and Geometric Means (GM), 1986

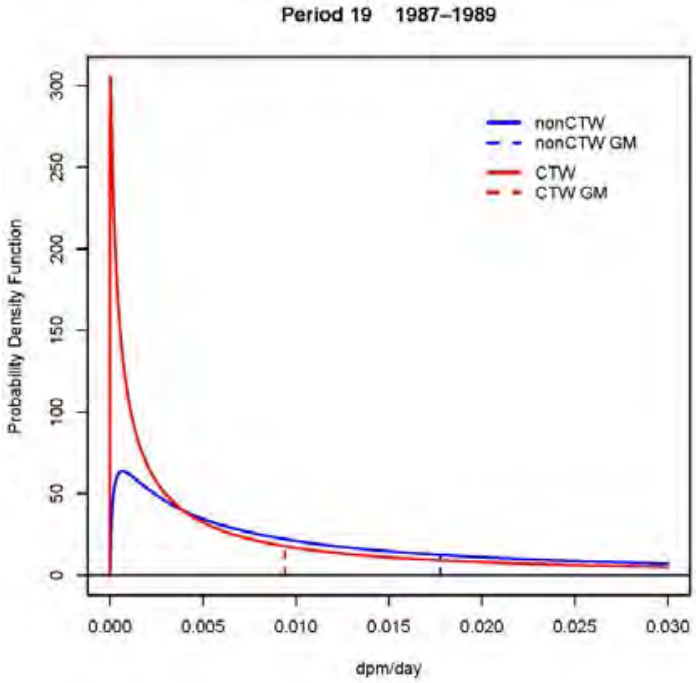

Figure A-19. Comparison of NCW and CTW Distributions and Geometric Mean (GM), 1987–1989