FINAL REPORT

AEROSOL RELEASES FROM THE IDAHO CHEMICAL PROCESSING PLANT 1957-1959

ADDENDUM TO

ATMOSPHERIC SOURCE TERMS
FOR THE IDAHO CHEMICAL
PROCESSING PLANT, 1957–1959

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Centers for Disease Control and Prevention
Atlanta, Georgia 30335

SC&A, Inc.
6858 Old Dominion Drive, Suite 301
McLean, Virginia 22101

SENES Oak Ridge, Inc.
102 Donner Drive
Oak Ridge, Tennessee 37830

Authors:

Robert P. Wichner, *SENES* Oak Ridge, Inc.
John-Paul Renier, *SENES* Oak Ridge, Inc.
A. Iulian Apostoaei, *SENES* Oak Ridge, Inc.

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1.0 INTRODUCTION AND SCOPE

This addendum to the main report, *Atmospheric Source Terms for the Idaho Chemical Processing Plant, 1957–1959* (Wichner et al., 2005), addresses the contribution from aerosol releases. The objective is to estimate total activity emitted per day as aerosols and the nuclide composition of the aerosols during this 3-year period.

The main report, which dealt with radioiodine emissions, contains full descriptions of the RaLa Process within the Idaho Chemical Processing Plant (ICPP), the ICPP off-gas system, and an overview of the ICPP. A few key features of the off-gas and stack monitoring systems are briefly reviewed here. The main assumption of this evaluation is that the recorded capture of so-called beta-minus iodine (β-I) beta emitters and alpha (α)-emitting nuclides in the stack sampler, translated into a daily releases to the atmosphere by means of a correlation, were due to aerosol particles.

As noted in the main report, the evaluation of atmospheric releases from the ICPP in the 1957 through 1959 timeframe is hampered by the lack of primary descriptive and interpretive reports. For aerosol releases, only a fragmentary description of the (β-I) measurement method is available and only from unpublished project letters. Nothing at all is available on the procedure for determining the α-emitters, presumably also captured in the stack sampler in these early years. Nor has any report been found on the identification of the nuclide contributors to either the (β-I) or the α-releases. Thus, there is a difficulty in interpretation of the readings.

Identification of the aerosol nuclides would be aided if their source were known. The ICPP off-gas flow combined four reprocessing lines, one of which was RaLa. Radioiodines clearly came from RaLa, since it was the only one processing short-cooled fuel. But the other three reprocessing lines may have contributed to the aerosol releases. In addition, some assumption is required as to formation mechanism in order to determine the age of the particles, which directly bears on the nuclides in the aerosol.

Finally, the correlation connecting the curie amount of (β-I) and α-material captured in the stack sampler to the atmospheric release needs to be evaluated. For radioiodines, this correlation included an efficiency term (assumed to be 50%) and a decay factor to account for the 24-hour sampling period, both of which have a direct bearing on the calculated release.

Presented in this addendum are the following:

- The daily record of (β-I) and α emissions as provided by the Stack Monitor Datasheets (Appendix A)

- Interpretation of the (β-I) and α emissions in terms of contributing nuclides (Appendix B and Table 6.1)

- Review and possible revision of the procedure for determining the daily emissions from the sampler inventory

- Summary of (β-I) aerosol releases presented as annual totals and totals per RaLa run
- Comparison of results with the INEL Historical Dose Evaluation (HDE) reconstruction study (HDE 1991)

2.0 SUMMARY OF THE IDAHO CHEMICAL PROCESSING PLANT OFF-GAS AND STACK SAMPLER SYSTEMS

Figure 2.1 shows a schematic of the ICPP off-gas system in the 1957-1959 time frame. The significant point is that the stack sampler draws from a combined airflow from several sources:

- On a volume basis, the stack flow consisted primarily of ventilation air from the main process building.
- A second source was vessel off-gas (VOG), drawn by suction from all ICPP process vessels, excluding dissolvers and all RaLa vessels.
- The non-RaLa dissolver off-gas (non-RaLa DOG) drew from the three non-RaLa dissolvers in the ICPP.
- The RaLa off-gas (shown as RaLa DOG) drew from all the RaLa process vessels, including the RaLa dissolver, centrifuges, process vessels and storage vessels.

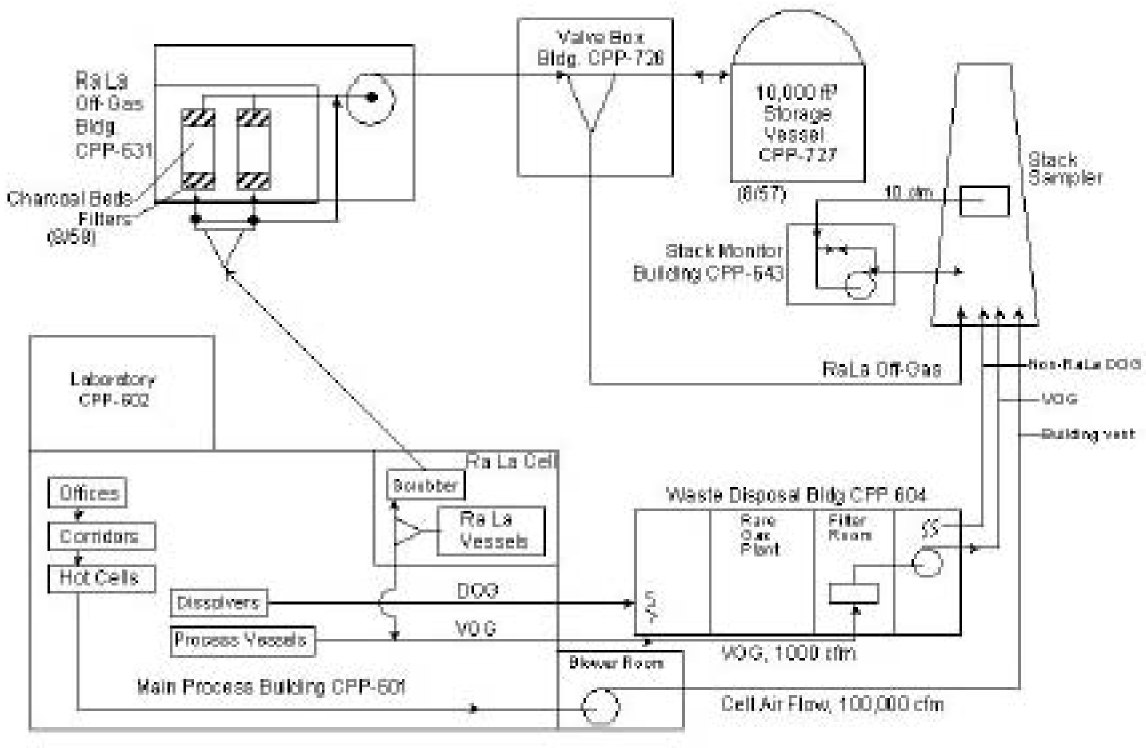


Figure 2.1 RaLa and Idaho Chemical Processing Plant off-gas flow schematic, 1957-1959

As noted in the main report, numerous piping interties and valve settings make other flow schemes possible, but the schematic shown is believed to be the predominant one.

During most of this period, the stack-sampling device consisted of about a 1-liter bottle fitted with a glass frit base through which the sampled air was bubbled. The flow rate through the sampling bottle was on the order of 0.2 ft^3/min (5.7 liter/min). The capture efficiency for gaseous iodine was administratively set at 50%, a value approximately borne out by numerous tests conducted in 1957.

From the brief discussion of the method for determining the curie level of (β-I) in the sampling bottle, it must be assumed that aerosols were captured in the sampling bottle liquid. No references to filters in the sampling system have been found for this time period. It is surmised that the α-emitting material was also determined from the residue of the sampling bottle contents after evaporation.

The capture efficiency of the sampling bottles for aerosols appears not to have been tested. It will be shown below from the listings in the stack monitor datasheets that a capture efficiency of 100% was assumed for aerosols. There appears to be no good way to evaluate aerosol capture efficiency from the information that is available, but 100% is probably too high.

Another difficulty in the interpretation of the (β-I) data is how to account for decay losses during the 24-hour sampling period when the contributing nuclides are not known. It will also be shown below that this was avoided by assuming no decay loss, i.e., only long-lived aerosol material was assumed to contribute to the (β-I) reading. This is certainly valid for the α-emitters, but not necessarily so for the (β-I) nuclides.

3.0 BETA-MINUS IODINE AND ALPHA RELEASE RECORD

3.1 Radiochemical Method for Beta-minus Iodine

Initial measurements of (β-I) activity were determined by heating the sampler liquid to near boiling, supposedly driving off the iodine, and measuring the resulting β activity. This was the method used in February and March 1957. It was soon recognized that this method did not drive off all the iodine (Rich 1957). The necessary correction, acidifying the sodium hydroxide-sodium thiosulfate sampler solution prior to heating, was made before run 3, April 5, 1957. Table 3.1 illustrates the effect of correcting the radiochemical procedure.

Table 3.1 Beta-minus iodine activity measured in the Idaho Chemical Processing Plant stack for the first four RaLa Runs as reported in the Health and Safety Division Annual Report, 1959

Run number	Date	(β-I) reported release Ci per run
1	Feb. 1-3, 1957	114.6 (incorrect)
2	Feb. 20-21, 1957	334.7 (incorrect)
3	April 5-6, 1957	1.3
4	May 19-20, 1957	6.6

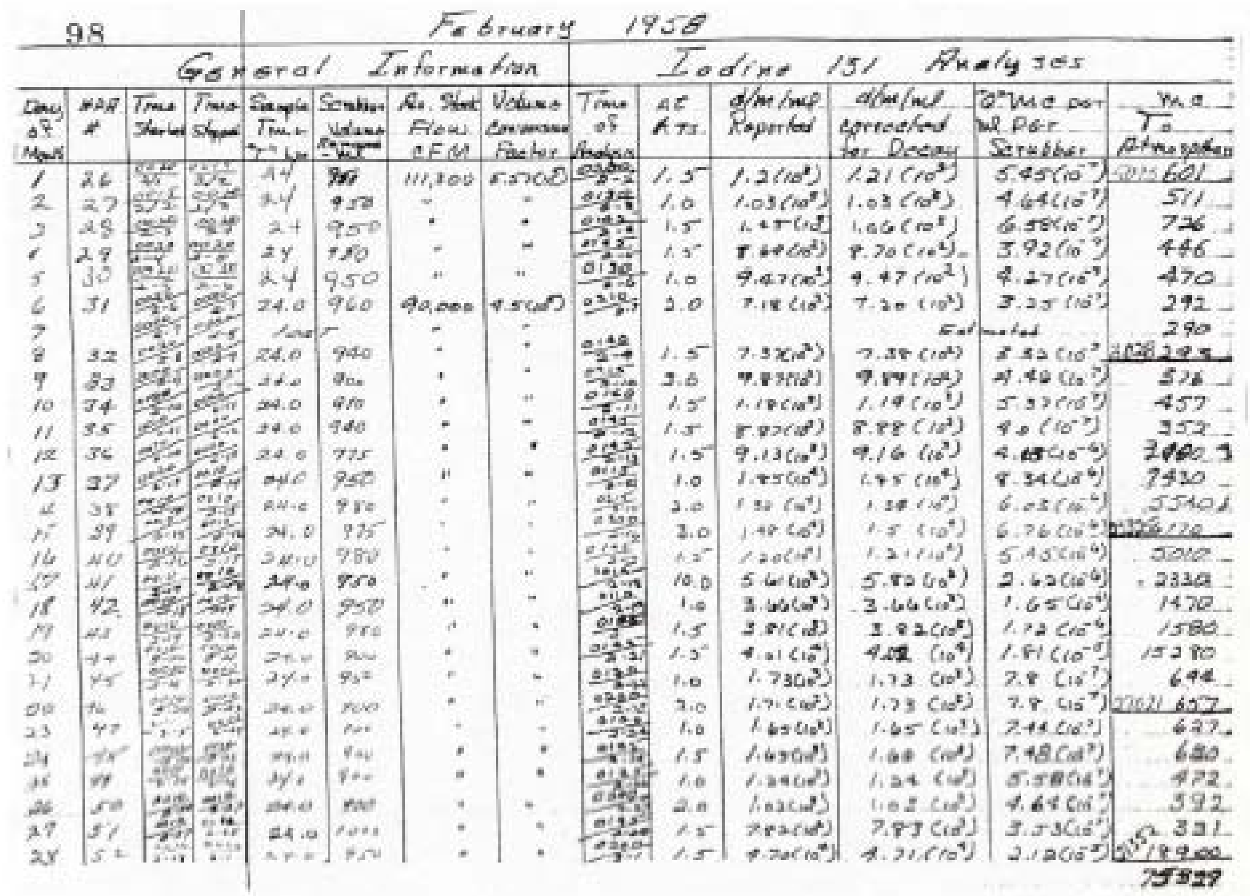
3.2 Radiochemical Method for the Alpha Determinations

No record has been found on the method for determining the α-emissions in the sampler solution. There is no mention of a particulate filter in the sampler line in this time frame. Therefore it must be assumed that the α-emitting particles were captured in the sampler solution. Counting would require evaporation to dryness and emplacement in geometry that counts all emissions, perhaps by a scintillation device that discriminates alphas from other radioactive emissions. (See Price 1958 for a contemporary α-counting method.)

3.3 The Beta-minus Iodine and Alpha Release Record

Figures 3.1 and 3.2 show a portion of the stack sampler data record (Stack Monitor Datasheets, 1957-1961) for February 1958. Figure 3.1 lists the date, sampler and stack flow-rates, sampler volume, I-131 sampler readings, and the calculated I-131 emissions. Figure 3.2 shows the (β–I) and α-readings in the sampler bottle and the calculated (β-I) and α emissions. The assumptions for calculating the emissions are discussed below.

The entire daily (β–I) and α-release record, a portion of which is shown in Figure 3.2, is reproduced as an Excel spreadsheet in Appendix A. For convenience, the I-131 release record is also recorded in this table taken from Appendix G of the main report. Further discussion of the Stack Monitor Data Sheets is given in Section 6.3 of the main report.



98 February 1958

General Information — Iodine 131 Analyses

Day of Month	HAR #	Time Started	Time Stopped	Sample Time hrs	Scrubber Volume	Av. Stack Flow CFM	Volume Conversion Factor	Time of Analysis	AC Hrs.	d/m/ml Reported	d/m/ml Corrected for Decay	μc I¹³¹ per ml per Scrubber	mc To Atmosphere

Figure 3.1 Portion of the first page of the stack monitor datasheet for February 1958

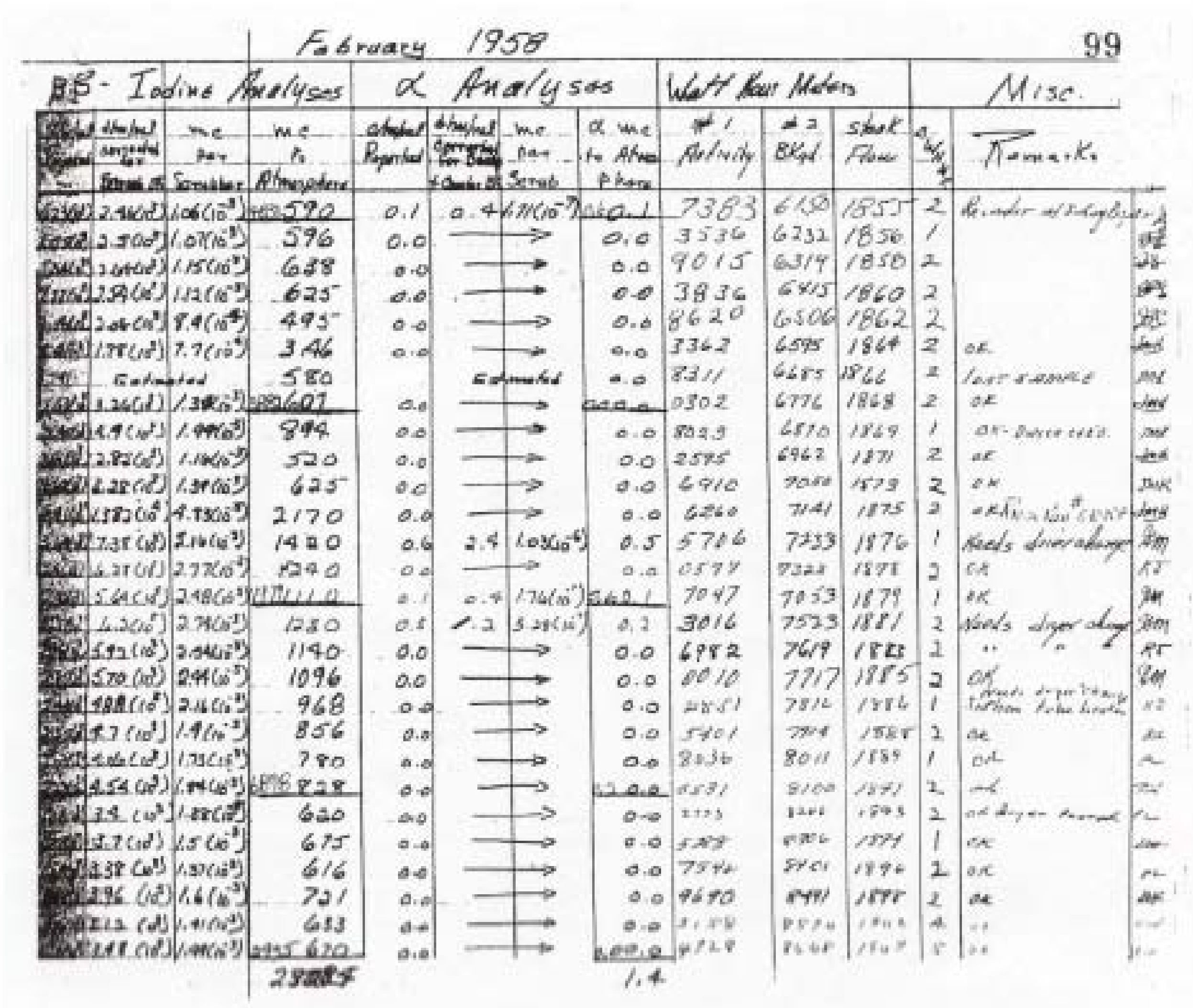


Figure 3.2 Portion of the second page of the stack monitor datasheet for February 1958

As noted in the main report, the Stack Monitor Datasheets were summarized in internal letters, the so-called Hayden Notegrams (1957-1961), which were then, without reference, summarized in the Health and Safety Division Annual reports (e.g., H & S Annual, 1959), and finally adopted in the INEL Historical Dose Evaluation (HDE 1991).

4.0 INTERPRETATION OF THE BETA-MINUS IODINE AND ALPHA RELEASES

4.1 Daily Record of Beta-minus Iodine and Alpha Releases

Figures 4.1, 4.2, and 4.3 plot the reported α and (β-I) daily measurements for the representative months of May 1957, October 1958, and October 1959, respectively.

We note first that the peaks in the α-readings seem generally to correlate with dates of RaLa runs. This is at least true for runs 4, 19, and 34 (but mysteriously not run 18). However, no other α-peaks are observed. Therefore, it seems reasonable to assume that the reported α-releases emanate from the RaLa fuel processing activity.

Similarly, the (β-I) release peaks seem to generally correlate with dates of RaLa runs, i.e., for runs 5, 18, 19, and 31.

It is important to note that not all (β-I) peaks correspond to I-131 peaks, and vice versa. The prominent I-131 peaks on May 22, 27, and October 15 have no corresponding (β-I) peaks. Also the prominent (β-I) peak of October 13 has no corresponding I-131 peak. These are important indications that the (β-I) readings were not simply residual iodine. (However, confirmation by at least one γ-spectrometer reading would have been extremely informative.)

Note the release behavior on October 16, 1959, the date of the criticality accident. (See Section 8 of the main report for a discussion of this accident.) There was a high (β-I) peak corresponding exactly to an I-131 peak, but there is no α-peak. Undoubtedly, the reason for the absence of an α–peak following the criticality accident is the absence of significant α activity produced in the brief criticality of an HEU solution. As shown below, the principal α activity in the RaLa peaks was the Pu-238 produced during Material Testing Reactor (MTR) irradiation. There were only minute amounts of Pu-238 produced in the criticality.

Conclusion regarding α and (β-I) release data. Though there are some unexplained details, the general view that the (β-I) and α readings represent aerosol emissions appears to be valid. Moreover, the daily record shown in Figures 4.1, 4.2 and 4.3 seem to indicate the source was the RaLa process solutions, except for the criticality accident.

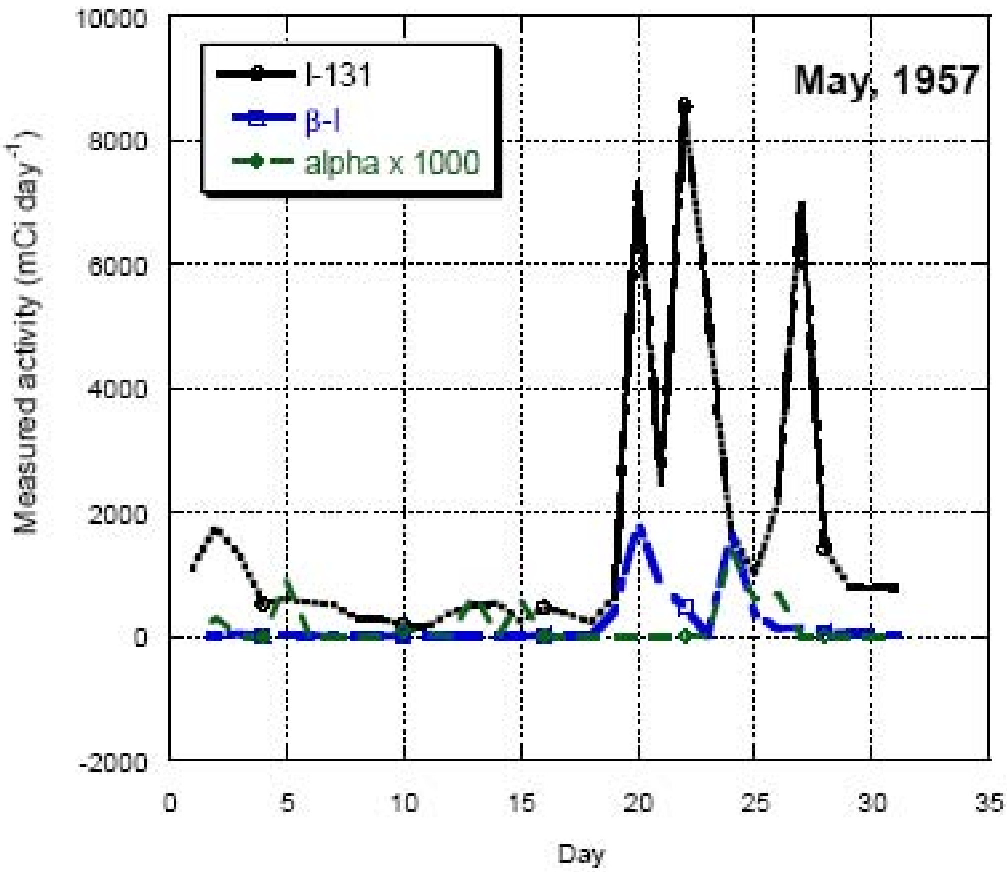


Figure 4.1 Measured activity in the Idaho Chemical Processing Plant stack during May 1957

RaLa Run #4 took place on May 19 –20

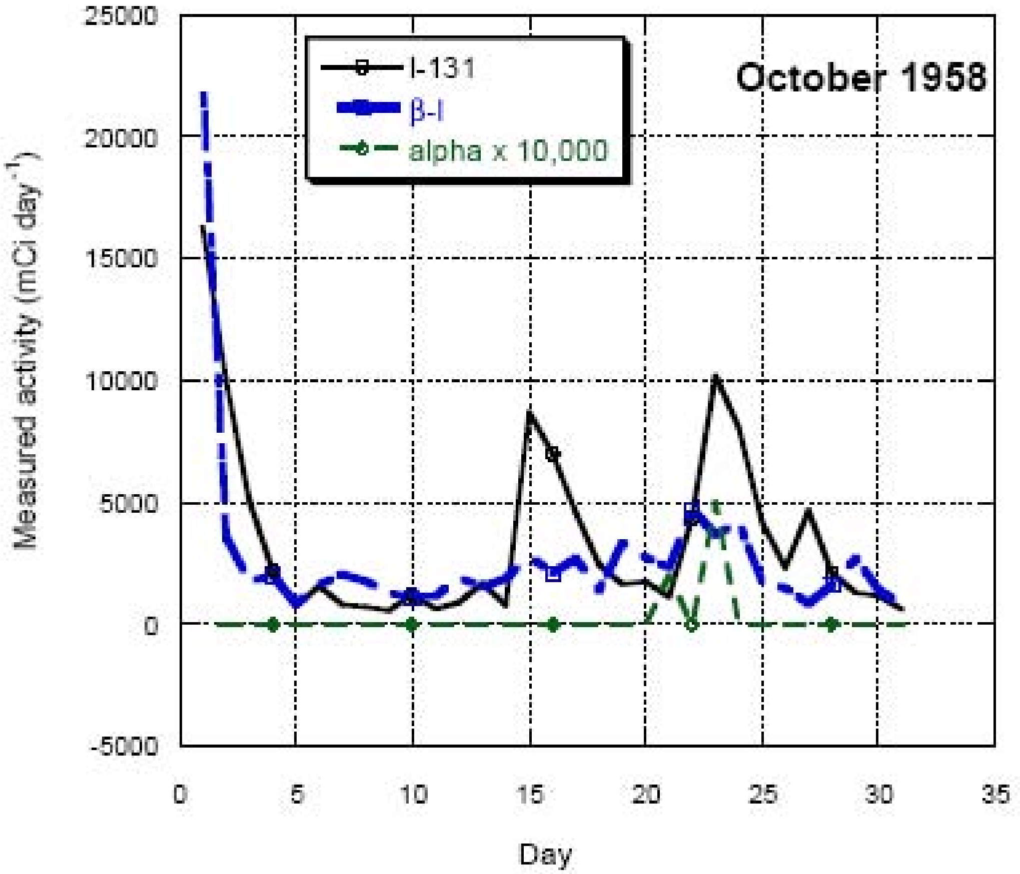


Figure 4.2 Measured activity in the Idaho Chemical Processing Plant stack during October 1958

RaLa Run #18 took place on October 1 (1-day run)
RaLa Run #19 took place on October 22 (1-day run)

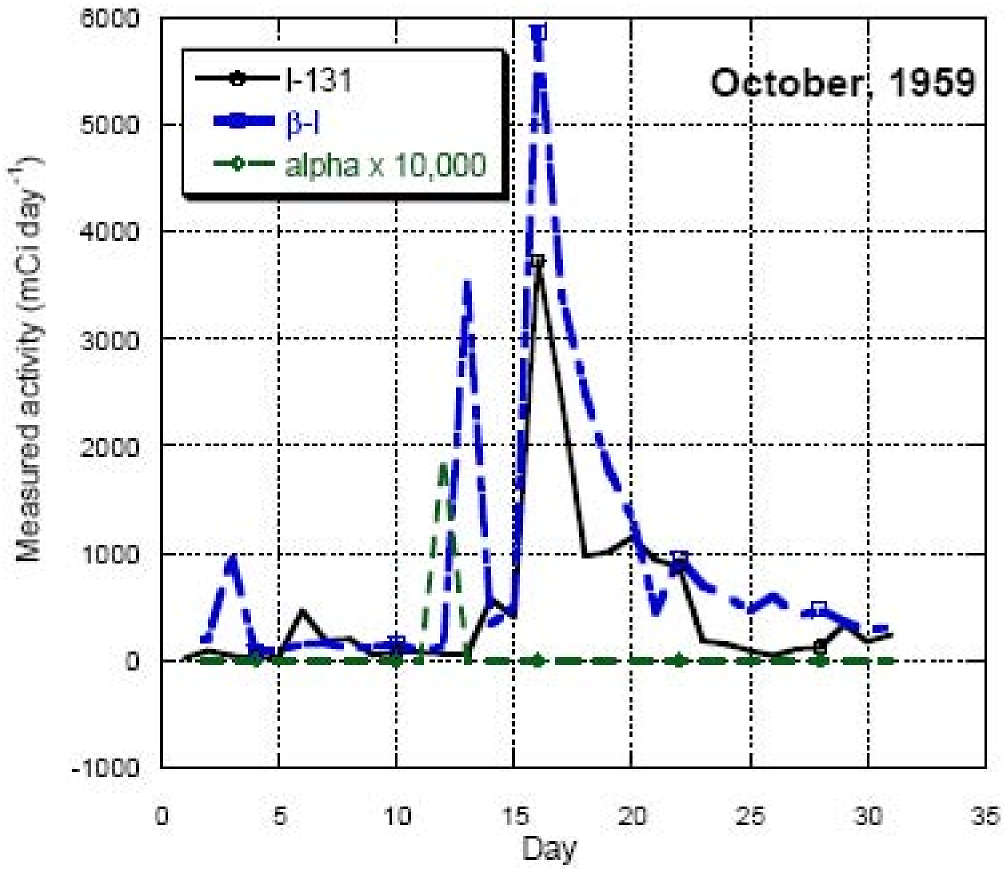


Figure 4.3 Measured activity in the Idaho Chemical Processing Plant stack during October 1959

RaLa Run # 34 took place on October 13-14

The criticality accident took place on October 16

4.2 Major Alpha-emitting Nuclides

As noted, Figures 4.1, 4.2, and 4.3 seem to indicate that the α-emitting aerosols were formed from RaLa process solutions, perhaps from dried droplets or from splatter and subsequent liftoff. In such case, the α-emitters would be representative of the RaLa process solution.

Table 4.1 lists the major actinide α-emitters in a typical 2-day cooled MTR element designated for use in RaLa as determined by an ORIGEN2 calculation.

The actinide levels were calculated assuming a "typical" highly enriched uranium (HEU) diffusion plant product of 93.5% U-235 and 6.5% U-238. The actual feed composition may vary somewhat case to case. Also note that the α-decay chain products of the three uranium isotopes were assumed to be zero in the as-charged fuel element. These would depend on the age of the diffusion plant product at the time of insertion of the fuel element into the MTR. These approximations should have a minor effect on the results in view of the extremely low level of α-emissions observed in the stack sampler solutions.

Table 4.1 Major actinide alpha-emitters* in a typical 2-day cooled RaLa fuel element

Nuclide	% Contribution to the activity (Ci)
U-234	0.253
U-235	0.121
U-236	0.331
Pu-238	95.947
Pu-239	1.358
Pu-240	0.846
Cm-242	0.990

*All actinide α-emitters contributing more than 0.1% to the total actinide curie level in the fuel element (including β-emitters U-237, Np-238, Np-239).

The table shows that the major α-emitting actinide aerosol was Pu-238 with minor contributions from Pu-239, Pu-240, and Cm-242, and even lesser contributions from U-234, U-235, and U-236.

It should also be noted that the α-decay chain products of the actinides listed in Table 4.1 would also be present in the aerosol, contributing to the total measured α Ci level. Thus the mix of nuclides in the aerosol is more complex than the composition shown in the table, which includes only the actinides. A more complete portrayal of the composition would include the various decay chain products of the actinides listed in the table. However, inclusion of the decay products would not affect the total alphas measured in the stack, only the composition (see Section 6 – Results and Discussion). Of course, the decay chain products are accounted for in the determination of the dose from exposure to the above actinides.

5.0 NUCLIDES COMPRISING THE BETA-MINUS IODINE READINGS

5.1 Beta-minus Iodine Aerosol Formation Mechanism

Above it was shown that the time trace of the (β-I) release readings correlated roughly with RaLa run dates and therefore was probably produced by some RaLa processing activity. Formation mechanisms could have been the following:

(1) Dryout of droplets formed from pumping or sampling the RaLa process solutions either directly from the dissolver and other process vessels, or delayed release from dried out splatter.

(2) Daughters of volatilized iodine, xenon, bromine or krypton from the RaLa process solutions.

(3) Adsorption of iodine or other volatilized material onto carbonate aerosols produced by reaction of the alkaline scrubber solution with carbon dioxide.

(4) Dusts associated with the operation of the charcoal beds.

(5) There remains the possibility that the (β-I) activity was actually residual I-131 and other radioiodines, incompletely driven off from the sampler solution by the acidification and heating process. However, as the above discussion showed, the (β-I) and I-131 peaks occasionally did not correspond, suggesting that the (β-I) readings were probably not residual radioiodines.

Mechanism 1 appears to be the most likely formation method although mechanisms 3 and 4 may also contribute.

Mechanism 2 could be eliminated by noting that few solid radioactive daughters of the volatile material would exist in 2-day cooled fuel.

Mechanism 5 remains a possibility. However, the non-correspondence of some (β-I) peaks with I-131 peaks seems to indicate that this was not the case. (It is unfortunate that γ-spectroscopy analysis of the (β-I) material was not performed; at least, none have been found.) The analysis of (β-I) activity outlined below is based on the assumption that mechanism 1 was the command aerosol production method.

5.2 Calculation of Beta-minus Iodine Releases from Measured Sampler Activities

Section 5.2 of the main report (Wichner et al. 2005) describes the relationship between the radioiodine sampler activity and release to the atmosphere, as used by ICPP personnel for I-131 and I-132. The situation is quite different for (β-I) aerosol releases in that the individual isotopic activities were not known. Hence, the decay correction for the 24-hour sampling period could not be applied. In addition, no measurement was ever made (or none has been found) on the efficiency of aerosol capture in the sampler. As a result, ICPP personnel assumed 100% capture efficiency for aerosols in the sampler.

These two considerations led to the following simple relationship between (β-I) releases to the atmosphere and the measured sampler (β-I) activity employed by ICPP personnel:

$$R_{reported} = A_m \, Q_{stk}/Q_{sampler} \qquad (5.1)$$

where,

$R_{reported}$	reported (β-I) atmospheric releases per sampling period, Ci
A_m	(β-I) activity measured in the sampler at the end of the 24-hour sampling period, Ci
Q_{stk}	stack air flowrate, m^3d^{-1}
$Q_{sampler}$	sampling flowrate, m^3d^{-1}

Values of $R_{reported}$ determined by Equation 5.1 were recorded in the Stack Monitor Datasheets (1957-1959) for each day of RaLa operation, from February 1957 through December 1959, and beyond. These values are reproduced in Appendix A.

Actual (β-I) releases differed from the reported releases for at least the following two reasons:

- The sampler capture efficiency for aerosols was undoubtedly less than 100%. No measurement has been found, but our judgment is that 50% efficiency is a more realistic estimate, which is the same as the assumed capture efficiency for radioiodine.

- Decay correction factors, if they could be applied, would tend to elevate the releases. These would be corrections both for decay in the sampler during the 24-hour sampling period and for the delay time before counting.

Adopting the mechanism 1 view of aerosol formation and further assuming that each nuclide contributes an equal fraction of its current inventory in the RaLa system to the aerosol material leads to the following:

$$R_i(t_n) = a \, A_{d,i}(t_n) \qquad (5.2)$$

where,

$R_i(t_n)$	=	release of nuclide i to the atmosphere during sampling period on day t_n, Ci
a	=	dimensionless factor
$A_{s,i}(t_n)$	=	activity of nuclide i in the RaLa system on day t_n after removal of the element from the MTR, Ci

Using Equation 5.2 as the principal assumption, Appendix B outlines a method for correcting the reported releases determined by Equation 5.1 that accounts for decay in the sampler during the sampling period and the delay time prior to counting. In addition, the individual nuclides contributing to the total (β-I) release may be identified.

As shown in Appendix B,

$$R_{corrected} = R_{reported} \cdot \frac{1}{f} \cdot \frac{\Sigma A_{d,i}}{S} \quad (5.3)$$

where,

$R_{corrected}$ = decay and sampler efficiency corrected (β-I) release to the atmosphere, Ci

F = sampler efficiency

S = $S = \sum_i A_{d,i} \; Y_i \frac{1 - \exp(-\lambda_i \; t_s)}{\lambda_i \; t_s} \exp(-\lambda_i \; t_w)$ (See Appendix B)

Y_i = the number of β-particles and ejected electrons emitted per disintegration that may be read by the 1957 detectors. (See discussion in Appendix D.)

λ_i = decay constant of nuclide i, sec^{-1}

t_s = sampling duration, usually 24 hours

t_w = time delay from sample withdrawal to counting, sec

The major correction compared to the reported releases is due to assuming a sampler efficiency of 50% compared to 100% assumed in the Stack Monitor Datasheets. This effectively doubles the reported daily releases listed in Appendix A. As shown in sample calculations in Appendix B, the correction due to the factor $\Sigma A_{d,i}/S$ is on the order of 7% to 14%, depending on t_n.

Early records in the Stack Monitor Datasheets indicated that t_w ranged from 3 to 72 hours, with an average of 14 hours, at least for the month of April 1957. Since t_w had a minor impact on 8.3-day I-131, it ceased to be recorded early in 1957. The average t_w of 14 hours was assumed for the computation of the Appendix C tables.

The factor Y_i is required to account for the fact that some of the disintegrations emit betas too weak to be read by 1957 detectors. The discussion in Appendix D concludes that betas less than about 25 keV energy would not have penetrated the 1957 detector window. Nevertheless, such nuclides are included by ORIGEN2 as contributing curies, but in fact were not counted for at least a portion of the disintegrations. As seen in Appendix C, Tc-99m, Ru-106, and Ba-137m fall into this category.

The factor Y_i also corrects for cases where the total β plus e- emissions greater than 25 keV exceed unity per disintegration by virtue of knockout of interior orbital electrons by γ-rays. The Appendix C listing shows that U-237 and Np-239 fall into this category.

It is further shown in Appendix B that the assumption embodied in Equation 5.2 enables identification of the contributions of individual nuclides to the total release, in accordance with the following equation:

$$R_i(t_n) = R_{reported}(t_n)\frac{A_{d,i}(t_n)}{f\,S(t_n)} \qquad (5.4)$$

where

$R_i(t_n)$ = emission of radionuclide i on day t_n, Ci

That is, the factor $A_{d,i}/(f\ S)$, computed for each day for the solid fission products and β-emitting actinides using ORIGEN2, when multiplied by the reported release for that day from Appendix A, yields the contribution to the release by nuclide i. Such contributions are listed in the fourth column of Table C.1 for each of 3 to 33 days following withdrawal from the MTR, and in Table C.2 for the eight days following the October 16, 1957, criticality accident.

5.3 Estimation of Alpha-emitting Aerosols

Since the α-emitters are generally fairly long-lived actinides, the decay corrections used for the (β-I) readings are not necessary. Including only a sampler efficiency correction leads to the following:

$$R^{\alpha}_{corrected} = R^{\alpha}_{reported}/f \qquad (5.5)$$

where,

$R^{\alpha}_{reported}$ = α -emissions listed in the stack monitor data sheets for each day, reproduced in Appendix A, Ci

f = sampler efficiency

As for the (β-I) emissions, a sampler efficiency of 50% is assumed, because it is judged to be more reasonable than the 100% efficiency assumed by ICPP analysts. In addition, the mixture of α-emitters is not likely to significantly change during the time between RaLa runs. Therefore, the composition of the α-emitting aerosols may be identified by examining a typical mixture given by ORIGEN2. Thus the actinide mixture shown in Table 4.1 should be typical for the α-emitting aerosols for all days following the dissolving. As noted, Pu-238 dominates the α-activity, with about 96% of the total.

5.4 Calculation Procedure and Nuclides Comprising the Beta-minus Iodine Material in RaLa Aerosol Emissions

Equations 5.2 through 5.4 indicate the procedure for estimating a typical aerosol release and its composition. It should be emphasized that these results are only "typical" because of the incomplete information on the inventory of nuclides in the RaLa feed elements[1] and the approximate nature of the assumption expressed in Equation 5.2. We have arbitrarily selected the feed element for RaLa run 2 as typical and assumed the nominal 2-day cooling prior to insertion into the dissolver. The calculation proceeds as follows:

- Nuclide inventories for the selected feed element are determined from ORIGEN2 for the selected typical element. Gases and halogens are removed from the list; the rest are assumed to contribute to the aerosols. Beta-emitting actinides, listed separately by ORIGEN2, are included with the fission products, which are all β-emitters. Inventories are calculated for a range of decay times, from an assumed 2-day decay prior to insertion to the maximum number of days between runs. Appendix C lists these inventories out to 33 days cooling time (i.e., 1-30 days after dissolving).

- The factor Y is determined for each nuclide from information contained in ORIGEN2. As noted above, Y is the average number of betas and knockout orbital electrons emitted per disintegration that would be counted by the 1957 vintage detectors. The effect of the parameter Y is seen in the Appendix C tables in the column labeled "Effective Activity."

- The parameter S for Equations 5.3 and 5.4 is determined by summation for each day after dissolving, enabling calculation of $R_{corrected}$, and the contributions from the individual nuclides. Appendix C lists these %-contributions to the total (β-I).

- Corrected total atmospheric releases are determined using the above parameters in conjunction with the reported daily releases reproduced in Appendix A. The composition for each day was used, starting with $t_n = 3$ for the first day of the dissolving, up to the day in which the next RaLa run was started.

This procedure was suggested by the method used in the Historical Dose Evaluation study (HDE 1991) and perhaps is a refinement thereof. The refinements include (1) a better estimate of the fuel element inventory (though still merely typical), (2) an accounting for the decay of individual nuclides in the sampler and prior to counting, (3) a more inclusive β-emitting nuclide list using ORIGEN2, and (4) an accounting of the effective activity based on countable emitted betas and electrons.

Table 5.1 reproduces a portion of the first day results, taken from Appendix C.1. Nuclides contributing less than 0.1% were rounded off to zero and omitted from Table 5.1, but included in Table C.1. Note that La-140 and Ba-140 are prominent contributors to the (β-I) release. Since the RaLa process efficiently separated this product from the balance of the flow stream, the contributions to aerosol release undoubtedly were different from that indicated in the tables. How different depends on precisely where in the system the aerosols are produced.

[1] Chapter 4 of the main report describes the difficulties encountered in attempting to identify the fuel elements fed to the dissolver, their decay times, and composition.

Table 5.1 Major contributing nuclides (>0.1%) to the beta-minus iodine reading during the first day of a typical RaLa run (i.e., t_n = 3)*
Determined from Equation 5.4

Isotope	Activity Ci	Effective Activity† Ci	Fraction‡ %
La-140	47,750	49,100	11.016
Pr-143	43,940	43,940	9.858
Ba-140	43,890	52,200	11.712
Ce-141	30,630	37,820	8.485
Mo-99	30,270	30,900	6.933
Tc-99m	29,160	3,218	0.722
Te-132	23,790	29,980	6.726
Zr-95	22,090	22,120	4.963
Y-91	21,670	21,670	4.862
Sr-89	18,920	18,920	4.245
Nd-147	15,520	25,170	5.647
Ce-143	14,410	17,390	3.902
Ru-103	14,180	14,360	3.222
Rh-103m	12,780	11,530	2.587
Nb-95	9,167	9,181	2.06
U-237	7,647	17,100	3.837
Pm-149	6,646	6,665	1.495
Pr-144	5,184	5,184	1.163
Ce-144	5,183	6,021	1.351
Nb-97	3,438	3,445	0.773
Zr-97	3,420	3,425	0.768
Rh-105	1,885	1,893	0.425
Sm-153	1,652	2,641	0.593
Pm-148	1,310	1,314	0.295
Te-127	965	966	0.217
Sb-127	962	1,017	0.228
Te-131m	849	1,009	0.226
Np-239	846	1,966	0.441
Pm-151	773	957	0.215
Y-93	506	507	0.114
Np-238	324	496	0.111
Total (listed nuclides)	**419,757**	**442,104**	**99.19**
Total (all nuclides)	**427,042**	**445,709**	**100.00**

* I.E., Three days after removal from the MTR

† The effective activity is given by the number of electrons (detectable by the 1957-1959 β-detector) per disintegration; expressed in Curies (see Appendix D).

‡ The fractional contribution to the recorded (β-I) release, calculated using the effective activity.

5.5 Possible Uncertainty Ranges of Aerosol Releases

As already noted, the radiochemical analysts who reported the millicurie readings in the stack sampler assumed a sampler efficiency of 100% for aerosols in their model for converting the reading to atmospheric emissions. There were no studies of the capture efficiency of the aerosols in the stack sampler. This study assumes a sampler efficiency of 50%, which appears to be more reasonable than 100%.

The contemporary analysts made no correction for radioactive decay during the 24-hour sampling period. Such corrections were not necessary for the alpha-readings, which were presumably caused by relatively long-lived actinides. Decay corrections for the (β-I) emitters were not possible because the individual nuclides contributing to the reading were not known.

The contemporary analysts made no corrections for plateout in the sampling line, nor were studies performed on aerosol plateout. The contemporary analysts assumed no sampling line deposition in converting the alpha and (β-I) readings in the sampler to releases to air.

5.5.1 Aerosol Production Methods

Possible aerosol production mechanisms in the RaLa system are discussed in Section 5.1. In the absence of any data, it may be conjectured that aerosols may have been produced by the following mechanisms:

- Droplets from the aeration of the dissolver liquid as a part of the sampling protocol
- Droplets produced during various processes in the centrifuge
- Reaction of sodium hydroxide vapor from the dissolver and scrubber solutions with carbon dioxide introduced with air to produce carbonates
- Dust from the charcoal absorbers
- Spallation from dried out liquids in the RaLa piping system

As seen from this list, aerosol properties would be difficult to surmise given the total absence of data. Consequently, estimating the error range in the reported releases to air can only be highly approximate and must rest heavily on judgment.

5.5.2 Sources of Uncertainty

The two most likely major sources of uncertainty in the reported aerosol releases are the uncertainties in the capture efficiency of the sampler solution and the uncertain degree of plateout in the sampling line.

(1) Capture efficiency in the sampler solution. As noted, 50% capture efficiency has been assumed as the basis of the reported releases in Appendix A.

Even if aerosol properties were known, a correlation for determining the capture efficiency in the sampler would be difficult to obtain. The process of bubbling aerosol-containing gas through a sampler bottle is a poor method for capturing the aerosols contained in the gas. As a consequence, it is not much studied. No commercial device relies on this method of aerosol removal (Lapple, 1954).

Recommendation: Since there are no capture efficiency data and there does not appear to be a method for determining a most probable sampler efficiency, a flat distribution ranging from 20% to 80% seems reasonable. This corresponds to an average of 50%, as assumed in this study.

(2) Plateout. The results presented in Appendix A are based on an assumed zero plateout in the sampler line.

The degree of plateout in the sampling line would be difficult to predict with confidence, even with a great deal more information. As it is, we have no information on the aerosol properties in the 1957-1959 time frame.

The sampling line as described in Chapter 6 of the main report (Wichner et al. 2003) reflects its condition until November of 1957, at which time it underwent extensive modifications. Until this date the line consisted of 1/2-inch schedule 40 pipe, 130 feet long, and the sampler flow rate was 5 CFM. No information was found on the system as modified in November 1957. Speculatively, it is possible that the length of the line may have been shortened by moving the stack sampler nearer to the stack. Most likely the diameter and flow rate were unaltered.

This uncertainty in both the aerosol and the sample line properties (after November 1957) renders the always-uncertain prediction of plateout completely conjectural. Nevertheless, it may be useful to discuss the range of possible values for the plateout.

Plateout in the Sampling Line (speculative). Aerosol deposition mechanisms and correlations are most conveniently summarized in Wichner (1991). First, it must be recognized that the gas flow in the sampler was well into the turbulent regime.[2] Therefore, the particles were well mixed in the central core of flow and transported to the surface across the buffer layer and the laminar sublayer by various methods.

- Diffusion. Particles less than about 0.1 micron diameter take on a significant effective diffusion coefficient, such that transport across the non-turbulent wall layers may occur via Brownian diffusion.

[2] The flow of 5 CFM in a 1/2-inch schedule 40 pipe at room temperature yields a Reynolds Number 12,000, well into turbulence. Hence, the well-known laminar flow correlations in Aerosol (1976) do not apply.

- Thermophoresis. Aerosols may be impelled to a cold surface from a hot gas due to differences in molecular velocities. This may be an effective deposition mechanism in the winter. Thermophoresis deters deposition, however, in the summer.

- Inertial impaction. This mechanism is effective for deposition in pipe fittings or for deposition around obstacles in the flow.

- Turbulent transport plus inertial impaction. If sufficient turbulent velocity is imparted to the particle towards the wall, its momentum may carry it through the wall layers.

Results. Mechanism (4) was tested to gain some rough idea of plateout in the sampling line using the correlations outlined in Wichner (1991). The reasonable assumption of a 2-micron particle diameter with a density of 5 g/cc yielded a 50% deposition in the 1957-configured sampling line, via mechanism (4) alone.

However, extreme sensitivity was found with respect to both assumed aerosol size and density. A 1-micron particle deposited only from 1%–15% for all reasonable particle densities. Particles of 6 microns and larger deposited completely for all densities above 2 g/cc. Loose flocs with a density of 1 g/cc deposited about 85% of the 6-micron particles. Of course, all particles that reach the surface would not necessarily stick there, reducing the estimated plateout in each case.

These results seem to indicate that 50% deposition (determined for a 2-micron diameter particle of density 5 g/cc) is a good generic postulation, although it retains a wide degree of uncertainty.

Recommendation. A reasonable judgment is that plateout ranged from 30%–70% with a flat distribution. This yields an average plateout of 50%, as indicated for a 2-micron particle with a density of 5 g/cc. In view of all the aerosol and sampler line uncertainties, a rather wide distribution of values, all equally probable, would seem to be indicated.

6.0 RESULTS AND DISCUSSION

6.1 Beta-minus Iodine Releases - Deterministic Results

The total daily (β-I) releases were determined using Equation 5.3 from the reported daily releases, reproduced in Appendix A corrected for an assumed sampler efficiency of 50% and decay prior to counting. The missing data for runs 1 and 2 were reconstructed from the observed releases for runs 3 through 8, which averaged about 12.5 Ci per run. Thus the “observed” releases for runs 1 and 2 were assumed to be 12.5 Ci each, distributed in time similar to RaLa run 4.

The corrected daily releases are available electronically, but as noted above, are twice the reported releases listed in Appendix A multiplied by a decay correction factor of approximately 1.10.

Total (β-I) releases per run are listed in Table 6.1. The average release was 45.3 Ci/run, with a total of 1675.3 for the 3-year period. (Annual releases are listed below in Table 6.6, compared with the evaluation in HDE 1991). Figure 6.1 shows the daily releases of La-140 from the ICPP during October 1958. The predicted releases generally follow the trends for total reported (β-I) releases for October 1958 (Figure 4.2).

Individual nuclide compositions of the releases were determined for each day from February 1, 1957, through December 30, 1959, by means of Equation 5.4. This voluminous file is also available electronically. The daily compositions consist of 114 fission product nuclides plus β–decay and electron emitting actinides, which contribute a miniscule portion of the (β–I) release.[3] Annual summaries of the nuclide contributions to the (β–I) release are given in Table 6.2. The table includes all nuclides contributing more than 0.1% to the total release for the years 1957 through 1959.

[3] Alpha-emitting actinides also emit Auger and internal conversion electrons, some of which may be read by 1957-vintage (β–I) detectors. For example, about 8% of the Pu-238 disintegrations emit IC electrons in excess of 25keV. But β–decay and electron emissions from actinides contribute a tiny portion of the (β–I) reading.

Table 6.1 Estimated beta-minus iodine activity released per run for all radionuclides

Run no.	No. of days until next run	Date	Total Ci/run
1	19	February 1, 1957	27.9
2	44	February 20, 1957	27.8
3	44	April 5, 1957	3.0
4	36	May 19, 1957	15.3
5	79	June 24, 1957	14.3
6	26	September 11, 1957	11.4
7	14	October 7, 1957	23.6
8	77	October 21, 1957	87.6
9	37	January 6, 1958	59.9
10	29	February 12, 1958	58.4
11	34	March 13, 1958	27.7
12	14	April 16, 1958	20.4
13	28	April 30, 1958	52.7
14	5	May 28, 1958	66.2
15	65	June 2, 1958	116.6
16	7	August 6, 1958	33.3
17	49	August 13, 1958	170.1
18	21	October 1, 1958	138.6
19	21	October 22, 1958	68.0
21	84	November 12, 1958	157.6
22	21	February 4, 1959	36.4
23	21	February 25, 1959	14.1
24	21	March 18, 1959	17.7
25	21	April 8, 1959	23.7
26	20	April 29, 1959	60.0
27	22	May 19, 1959	48.8
28	26	June 10, 1959	59.7
29	15	July 6, 1959	18.4
30	21	July 21, 1959	18.8
31	21	August 11, 1959	21.1
32	21	September 1, 1959	8.9
33	21	September 22, 1959	10.6
34	3	October 13, 1959	11.9
Criticality accident	20	October 16, 1959	107.4
35	25	November 5, 1959	20.1
36	15	November 30, 1959	5.6
37	17	December 15, 1959	11.3
		Grand Total	**1,675.3**

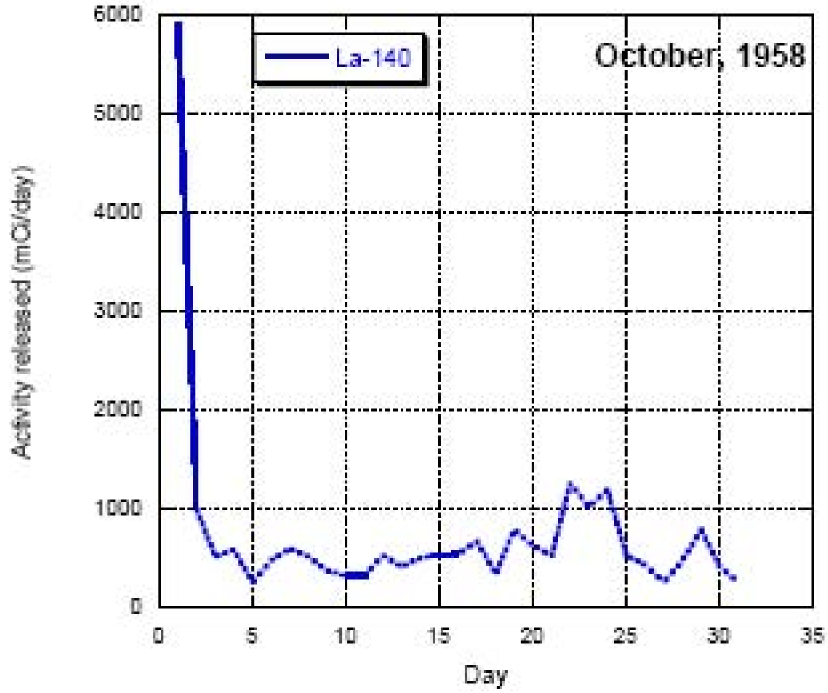


Figure 6.1 Predicted releases of lanthanum-140 from the Idaho Chemical Processing Plant during October 1958

RaLa Run #18 took place on October 1 (1-day run)
RaLa Run #19 took place on October 22 (1-day run)

Table 6.2 Nuclide composition of beta-minus iodine releases in curies: annual summary

Isotope	1957	Year 1958	1959	Total	Half-life T1/2	Units	Percent of total
La-140	21	101	51	173	40.272	hours	10.30%
Pr-143	20	94	48	162	13.56	days	9.66%
Ce-141	21	96	42	159	32.501	days	9.52%
Ba-140	18	89	46	154	12.74	days	9.17%
Zr-95	19	84	34	137	63.98	days	8.19%
Y-91	18	81	33	132	58.51	days	7.88%
Sr-89	15	68	28	112	50.5	days	6.66%
Nb-95	14	57	20	92	35.15	days	5.47%
Ru-103	10	47	20	78	39.28	days	4.67%
Rh-103m	9.5	43	18	71	56.12	minutes	4.21%
Nd-147	6.0	29	16	50	10.98	days	3.01%
Mo-99	5.4	24	20	50	66	hours	2.97%
Tc-99m	5.2	23	19	48	6.02	hours	2.84%
Te-132	4.6	21	16	41	78.2	hours	2.48%
Pr-144	5.6	23	9.1	38	17.28	minutes	2.27%
Ce-144	5.6	23	9.1	38	284.3	days	2.27%
Ce-143	1.7	8.1	13	23	33	hours	1.36%
U-237	2.2	10	5.2	18	6.75	days	1.07%
Nb-97	0.28	1.5	9.2	11	72.1	minutes	0.66%
Zr-97	0.28	1.5	8.8	11	16.9	hours	0.63%
Nb-97m	0.27	1.4	8.3	10	60	seconds	0.60%
Pm-149	1.0	4.7	3.8	9.6	53.08	hours	0.57%
Y-93	0.032	0.19	6.4	6.6	10.1	hours	0.39%
Sr-91	0.021	0.13	5.4	5.6	9.5	hours	0.33%
Rh-105	0.23	1.1	2.3	3.6	35.3	hours	0.22%
Y-91m	0.011	0.074	3.4	3.5	49.71	minutes	0.21%
Pm-147	0.54	2.16	0.78	3.5	2.6234	years	0.21%
Pm-148	0.33	1.55	0.77	2.7	5.37	days	0.16%
Rh-106	0.33	1.36	0.52	2.2	29.9	seconds	0.13%
Ru-106	0.33	1.36	0.52	2.2	368.2	days	0.13%
Y-92	0.00	0.00	2.1	2.1	3.54	hours	0.13%
Sm-153	0.24	1.09	0.73	2.1	46.7	hours	0.12%
Te-127	0.24	1.09	0.70	2.0	9.35	hours	0.12%
Te-129m	0.26	1.17	0.51	1.9	33.6	days	0.12%
Pr-145	0.00	0.00	1.9	1.9	5.98	hours	0.11%
Sb-127	0.20	0.92	0.67	1.8	3.85	days	0.11%
Total *	**209.4**	**951.7**	**514.2**	**1,675.3**			100%
Listed *	**207.5**	**943.2**	**506.7**	**1,657.5**			98.94%

* There are 115 nuclides released. The listed ones have a release greater than 0.1% of the total release.

6.2 Alpha-emitting Aerosols Releases – Deterministic Results

Daily releases of alpha-emitters as reported in the Stack Monitor Data Sheets are reproduced in Appendix A from start of operations in February 1957 through December 1959. Monthly summaries are given in Table 6.3.

Table 6.3 Monthly summary of alpha-emitting aerosol releases

	1957 mCi	1958 mCi	1959 mCi	Grand Total mCi
January	0	19.4	0.8	
February	161	1.8	0	
March	17.6	5.2	1.2	
April	4	6.8	0.6	
May	10.72	18.2	17.4	
June	2.16	24.4	4.8	
July	3.08	14.2	69.8	
August	3	11.4	4.8	
September	8.2	12	0.42	
October	10.8	1.4	0.38	
November	6.18	3.4	22.98	
December	9.6	0.8	2.92	
Total	**236.3**	**119.0**	**126.1**	**481.4**

Table 6.3 gives a set of estimated daily releases obtained, assuming that the stack monitor sampler has 50% efficiency (as opposed to 100% assumed by the contemporary operators). Thus, the daily estimates were obtained by multiplying the daily α releases reported in the datasheets by two. Note that units of Table 6.3 are mCi, and thus the α–releases are quite small compared with the (β-I) releases. The probable composition of the α-emitting aerosols is given in Table 4.1, where it is seen that about 96% of the α-aerosol emission is predicted to be Pu-238.

6.3 Analysis of Uncertainties in the Estimated Aerosol Releases

Section 5.5 identifies the capture efficiency of the sampler and the deposition in the sampling line (plateout) as the main sources of uncertainty in the estimated aerosol releases. However, the plateout is also a source of bias. Since some of the activity could have been lost due to deposition into the sampling line, the activity collected in the sampler could have been too low, and thus the deterministic releases presented in Sections 6.1 and 6.2 are also too low.

The overall effect of the uncertainties due to the unknown sampler efficiency and due to plateout (Section 5.5) can be expressed as an uncertain bias factor[4] of 2.13 with a 95% confidence

[4] The uncertain bias factor is calculated as [(0.5/Uniform(0.2,0.8))*(1/Uniform(0.3,0.7)], where the first term represents the correction for the unknown sampler efficiency, and the second term is the bias correction for the plateout. "Uniform (min, max)" is a uniform distribution between the minimum and the maximum specified values.

interval of 1.07 – 5.47. That is, all the releases presented in Sections 6.1 and 6.2 have to be multiplied by this factor to reflect the lack of knowledge about the sampler efficiency and the plateout. This uncertain bias factor applies in the same manner to all radionuclides, because the sampler efficiency and the plateout refer to particles in general, and depend on particle size, shape, mass, and density or on factors such as humidity and temperature, but they do not depend on the radioactive load of each aerosol. Similarly, the uncertain bias factor is assumed to apply in the same way to each day of release. Figure 6.2 is an example of the estimated daily releases of La-140 during October 1958, including the bias and the associated uncertainties. Table 6.4 presents the uncertainties in the (β-I) releases over the entire studied period (February 1957 – December 1959).

The uncertainty in the releases of alpha-emitting radionuclides is similar to the uncertainty in the (β-I) releases. When the uncertainty analysis is taken into account, the total activity of alpha-emitting radionuclides released from February 1957 to December 1959 is 1,020 mCi, with a 95% confidence interval of 516 – 2,630 mCi. About 96% of the alpha emissions are from Pu-238 (981 mCi with a 95% C.I. = 495 – 2,530 mCi).

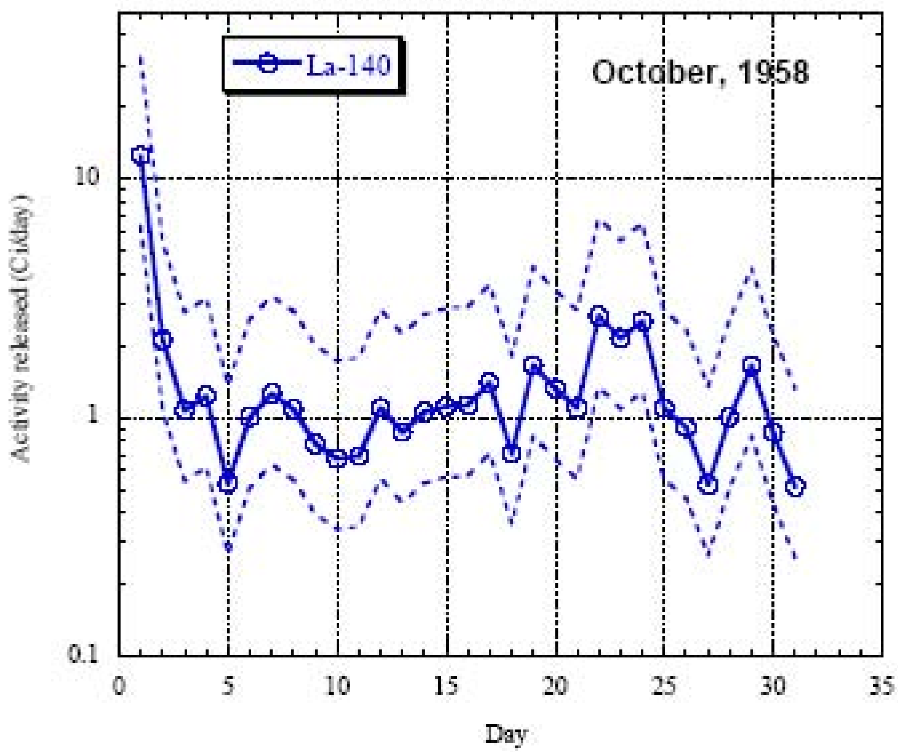


Figure 6.2 Predicted releases of lanthanum-140 from the Idaho Chemical Processing Plant during October 1958, and associated uncertainties

The dotted lines represent a 95% confidence interval about the central value
RaLa Run #18 took place on October 1 (1-day run)
RaLa Run #19 took place on October 22 (1-day run)

Table 6.4 Uncertainty in the estimated beta-minus iodine releases (curies)

Isotope	Release period: 1957 - 1959 95% confidence interval * Lower limit	Central value	Upper limit	Half-life T1/2	Units	Percent of total
La-140	185	367	944	40.272	hours	10.30%
Pr-143	174	344	886	13.56	days	9.66%
Ce-141	171	339	873	32.501	days	9.52%
Ba-140	165	327	841	12.74	days	9.17%
Zr-95	147	292	751	63.98	days	8.19%
Y-91	142	281	723	58.51	days	7.88%
Sr-89	120	237	611	50.5	days	6.66%
Nb-95	98	195	502	35.15	days	5.47%
Ru-103	84	166	428	39.28	days	4.67%
Rh-103m	76	150	386	56.12	minutes	4.21%
Nd-147	54	107	276	10.98	days	3.01%
Mo-99	53	106	272	66	hours	2.97%
Tc-99m	51	101	261	6.02	hours	2.84%
Te-132	45	88	227	78.2	hours	2.48%
Pr-144	41	81	208	17.28	minutes	2.27%
Ce-144	41	81	208	284.3	days	2.27%
Ce-143	25	49	125	33	hours	1.36%
U-237	19	38	98	6.75	days	1.07%
Nb-97	12	23	60	72.1	minutes	0.66%
Zr-97	11	22	58	16.9	hours	0.63%
Nb-97m	11	21	55	60	seconds	0.60%
Pm-149	10	20	52	53.08	hours	0.57%
Y-93	7.1	14	36	10.1	hours	0.39%
Sr-91	6.0	12	31	9.5	hours	0.33%
Rh-105	3.9	7.7	20	35.3	hours	0.22%
Y-91m	3.8	7.5	19	49.71	minutes	0.21%
Pm-147	3.7	7.4	19	2.6234	years	0.21%
Pm-148	2.9	5.7	15	5.37	days	0.16%
Rh-106	2.4	4.7	12	29.9	seconds	0.13%
Ru-106	2.4	4.7	12	368.2	days	0.13%
Y-92	2.3	4.6	12	3.54	hours	0.13%
Sm-153	2.2	4.4	11	46.7	hours	0.12%
Te-127	2.2	4.3	11	9.35	hours	0.12%
Te-129m	2.1	4.1	11	33.6	days	0.12%
Pr-145	2.0	4.0	10	5.98	hours	0.11%
Sb-127	1.9	3.8	9.8	3.85	days	0.11%
Total †	**1800**	**3563**	**9173**			
Listed †	**1780**	**3524**	**9073**			

* It includes the bias and the associated uncertainty introduced by the unknown efficiency and plateout.

† There are 115 nuclides released. The listed ones have a release greater than 0.1% of the total release.

6.4 Comparison of Aerosol Releases with the 1991 INEL Historical Dose Evaluation

6.4.1 The 1991 INEL Historical Dose Evaluation Method

The HDE (1991) methodology is described in Appendix A, starting on page A-37 of that report.

As in this study, the HDE task group assumed that the (β-I) readings represented aerosol emissions from the RaLa process captured in the stack monitor sampler bottle. Evidently, the run summary reports in AEC (1959), summed to yield annual (β-I) emissions, were used in the evaluation.

Alpha releases reported in the Hayden Notegrams[5] appear not to have been used. Alpha-emitters were included together with the (β-I) listing.

The HDE (1991) determined the radionuclide inventory in a "typical" RaLa feed element as follows:

- The inventories of Sr-89, Sr-90, Sr-91 and Ba-140, hand-calculated for an ideal irradiation and reported in Anderson (1959),[6] were used to determine the burn-up and specific power of the fuel element.

- RSAC-4 was then used to enumerate the principal fission products, assuming a nominal 2-day cooling period.[7]

The RSAC-4 total curies for each fission product were then adjusted proportionately to yield a sum equal to the (β-I) readings reported in AEC (1959)[8] for each year from 1953 through 1963. The releases reported in AEC (1959) are reported per RaLa run; these were summed and reported as annual releases.

HDE (1991) made use of the data on (β-I) releases as reported in AEC (1959), which presumed a capture efficiency of 100% in the stack sampler. This study assumed a 50% capture efficiency for those releases.

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[5] See main report for complete reference.

[6] See main report for complete reference.

[7] RSAC-4 evidently obtained the number of fissions from the burnup, assumed a thermal yield from U-235, and applied decay chain relationships during and after irradiation. There are some significant differences between RSAC-4 and ORIGEN2. Use of ORIGEN2 is described in Chapter 5 of the main report.

[8] See the main report for complete reference.

6.4.2 Methodology Differences between the 1991 INEL Historical Dose Evaluation and this Report

The major departure from the HDE (1991) method is in the use of the daily (β-I) and α-releases reported in the Stack Monitor Datasheets.[9] The HDE (1991) used only annual (β-I) releases, summing the releases per run as reported in AEC (1959).

The AEC (1959) report, evidently the basis for the (β-I) releases used in the HDE (1991) study, contained the following two differences from the assumptions in this study:

- The reported (β-I) release values for RaLa runs 1 and 2 in February 1957 are much too high in AEC (1959), due to an incorrect radiochemical method used for this period. Thus, the reported annual (β-I) release for 1957, reported in HDE (1991), is too high; the release is probably closer to 80-100 Ci instead of 520.2 Ci for 1957.

- The AEC (1959) (β-I) releases were based on an assumed 100% aerosol capture efficiency of the stack monitor sampler bottle. The capture efficiency for aerosol particles was never determined, but 100% is certainly too high. A judgment of this study is that the capture efficiency was probably closer to 50%. Accordingly, the stack monitor readings reproduced in Appendix A are too low by approximately a factor of 2.

- As in the HDE (1991) study, this report assumed a “typical” inventory of fission products in a 2-day, cooled feed element to the dissolver. The inventory of this selected typical element was determined using ORIGEN2 code, using cross-sections appropriate for the MTR, and based on the element fed to RaLa run 2. The complex irradiation history of this element was deciphered from the MTR Monthly Reports. (See Chapter 4 of the main report.) The HDE (1991) obtained the “typical” inventory from an early estimate of key fission product levels and an idealized irradiation history. RSAC-4 code was then used to flesh out the inventory. As noted below, there are some significant differences between the RSAC-4 and ORIGEN2 results.

- The HDE (1991) analysts seem not to have used the α-release readings reported in the Hayden Notegrams; they were not reported in AEC (1959),[10] the reference they used for RaLa emissions. As a result, some α-emitters were included in the (β-I) listing.

- An attempt was made in this study to determine the effect of emitted β and electron energy levels on the (β-I) readings taken by 1957 vintage β-detectors. As seen in the Appendix C tables, a few nuclides have effective activities higher than those determined by ORIGEN2, due to emission of orbital electrons sufficiently energetic

[9] See the main report for complete reference.

[10] See the main report for complete reference.

to be read by the 1957 β–detectors. A few nuclides (e.g., Tc-99m, Ru-106, and Y-91m) have lower effective activities due to emission of weak betas.

- The method outlined in Appendix B of this report enables application of decay corrections for each nuclide during sampling and delay prior to counting.

6.4.3 Comparison of Annual Releases with the 1991 INEL Historical Dose Evaluation

Table 6.5 shows the releases determined by the HDE (1991) study for 1957-1959, extracted from the reference Tables A-14 and A-15. The table shows estimates for annual aerosol release of 605, 648, and 448 Ci for 1957, 1958, and 1959, respectively. No breakdown is given in the HDE for the month or day.

Table 6.5 Annual releases of radionuclides reported by the 1991 Idaho National Engineering Laboratory Historical Dose Evaluation (HDE 1991)

Radionuclide*	1957 Ci/yr	1958 Ci/yr	1959 Ci/yr	1957-1959 Ci
Sr-89	19.2	14.8	7.6	41.6
Sr-90	35.0	49.8	40.9	125.7
Sr-91	0.92	1.0	0.4	2.4
Y-91	21.1	16.1	8.3	45.5
Nb-95	5.7	4.3	2.4	12.4
Zr-95	21.3	16.4	8.5	46.2
Ru-103	15.3	11.8	6.1	33.2
Ru-106	5.9	8.2	6.7	20.7
Te-132	34.1	30.6	15.1	79.8
Cs-134	0.5	0.8	0.6	1.9
Cs-136	3.2	2.2	0.5	5.9
Cs-137	35.7	50.7	41.7	128.1
Ba-140	58.5	46.7	23.7	128.9
La-140	63.1	49.6	25.3	138.0
Ce-141	33.2	25.7	13.1	72.0
Pr-143	57.9	45.6	23.2	126.7
Ce-144	54.0	73.9	59.7	187.6
Pm-147	140.0	200.0	164.0	504.0
Eu-154	0.071	0.100	0.082	0.253
Pu-238	0.078	0.112	0.091	0.281
Pu-239/240	0.012	0.016	0.013	0.041
Total (listed radionuclides)	604.8	648.4	447.8	1,701.0
Total (α-emitting nuclides)	0.089	0.13	0.10	0.32

*Includes only solid radionuclides.

Unexpectedly, Pm-147 (promethium) shows up as the dominant fission product, according to the HDE (1991), with annual releases of 140, 200, and 164 Ci for these 3 years. This is at odds with results of this study, shown in Table 6.2 and Appendix C, where La-140, Pr-143, Ba-140, and Ce-141 are the major contributors.[11]

Another significant departure from the results based on the ORIGEN2 results is the prominence of Cs-137. Appendix C tables show the Cs-137 contribution to be less than 0.1% at day 1 following the dissolving to less than 0.2% at day 50.

Comparison of α-Releases

Table 6.5 shows the annual alpha-release estimates reported by HDE (1991). The total level is about 0.1 Ci for each year (for a total of 0.3 Ci), composed primarily of Pu-238, Pu-239, and Pu-240. These releases compare fairly well with the efficiency-corrected releases of the Stack Monitor Data Sheets, as shown in Table 6.3, which indicate 0.24 Ci, 0.12 Ci and 0.13 Ci released during 1957, 1958 and 1959 respectively (for a total of 0.5 Ci). When the bias factor is taken into account (including the bias introduced by the unknown plateout), the total amount of alpha-emitting releases predicted by this study becomes 1.0 Ci (95% confidence interval of 0.52 – 2.6 Ci) for 1957 - 1959. This result is larger than that reported in HDE (1991), by an average factor of 3.

Table 6.6 Comparison of alpha-emitting actinide contributors to the aerosol release

HDE (1991)	This Study
(% contribution to the α-emitting actinide release during a normal RaLa run)	
Pu-238 (87.2%)	Pu-238 (96. %)
Pu-239/Pu-240 (12.8%)	Pu-239 (1.4%)
	Pu-240 (0.8%)
	Cm-242 (1.0%)

As shown in Table 6.6, this study concurs with HDE (1991) that the dominant alpha-emitting actinide was Pu-238, with small contributions from Pu-239, and Pu-240. This study shows a contribution from Cm-242 roughly on the par with Pu-239 and Pu-240.

Comparison of Annual Beta-minus-iodine Releases

Table 6.7 compares the annual (β-I) aerosol releases developed in this study with that reported by HDE (1991).

[11] The high Pm-147 level in the HDE (1991) summary table is so unlikely that one may suspect a typographical error.

Table 6.7 Annual beta-minus iodine aerosol releases—comparison to the 1991 Idaho National Engineering Laboratory Historical Dose Evaluation

	Type of analysis	1957 Ci	1958 Ci	1959 Ci	1957-1959 Ci
This study	Deterministic analysis	209	952	514	1675
	Uncertainty analysis *	446 (225-1148)	2023 (1022-5021)	1093 (552-2815)	3563 (1800-9173)
HDE (1991)		604.8	648.4	447.8	1701.0

* It includes the uncertainty and the bias introduced by the unknown efficiency and plateout. The numbers in parenthesis represent the 95% confidence interval about the central values obtained from the uncertainty analysis.

The high reported releases for 1957 in the HDE study are due to the inclusion of the erroneously high releases reported for February and March, which were caused by an error in the radiochemical method. In general, the β-I measurements indicate lower releases in 1957 than in 1958 or 1959, possibly due to improved operations.

Composition of the (β-I) Emitting Aerosols

The dominant (β-I) nuclides in each study are compared in Table 6.7. As seen, there are significant differences in the predicted composition of the (β-I) emitting aerosols between the ORIGEN2 results used in this study and the RSAC-4 results used in HDE (1991). The reasons are not at all apparent. Pm-147 seems to be an unlikely dominant nuclide in the HDE study and is difficult to rationalize.

Table 6.8 Dominant beta-minus iodine nuclides in this study compared with the 1991 Idaho National Engineering Laboratory Historical Dose Evaluation in approximate order of importance

This study	HDE (1991)
La-140	Pm-147
Pr-143	Ce-144
Ce-141	La-140
Ba-140	Ba-140
Zr-95	Cs-137
Y-91	Pr-143
Sr-89	Sr-90

7.0 SUMMARY AND CONCLUSIONS

(1) Examination of the (β-I) and α-releases record in the Stack Monitor Data Sheets indicates that these releases were probably due to aerosol emissions generated by RaLa process operations.

(2) Daily (β-I) and α-releases reported by the Stack Monitor Data Sheets are listed in Appendix A. These values are based on an assumed 100% capture efficiency of the stack sampler. It is judged that a sampler efficiency of about 50% is more likely than 100%, approximately doubling the historical releases reported in Appendix A. The efficiency is not well known, and its uncertainty can be described by a uniform probability distribution function with a range of 20% to 80%. This distribution has an average of 50% as discussed above.

(3) Daily (β-I) and alpha-releases reported in the Stack Monitor Data Sheets assume that no activity is lost by deposition in the sampling line (plateout). This study assumes that the amount of plateout could be 50%, resulting in an increase of the releases listed in Appendix A by an additional factor of 2. The true amount of plateout is unknown, but the uncertainty in this parameter can be described by a uniform probability distribution function with a range of 30% to 70% (an average of 50%). The assumed plateout value applies to both (β-I) and α releases

(4) The Appendix C tables list the nuclide compositions of the (β-I) aerosols for each day following the dissolving. These results are based on an ORIGEN2 determination of the nuclide inventory in a typical MTR-irradiated fuel element used for RaLa feed, with the modeling assumptions outlined in Appendix B.

(5) When the results of the uncertainty analysis are taken into account, the total annual (β-I) aerosol releases in this study are higher by a factor of 3 for 1958 and a factor of 2.4 for 1959, as compared to the releases reported by HDE (1991). The HDE (1991) releases are significantly higher for 1957. The discrepancy stems from the erroneously high values reported for February and March 1957, caused by an error in the radiochemical procedure used during these initial 2 months of operation.

(6) The compositions of the (β-I) emitting aerosols are significantly different between this study and HDE (1991). This study, by using ORIGEN2 code to simulate the radionuclide composition of fuel irradiated in the MTR reactor, predicts La-140 as the dominant nuclide as opposed to the unlikely Pm-147 for the HDE study. The present study also includes a much larger list of radionuclides than HDE (1991).

(7) The total alpha-emitting releases predicted by this study are quite low: 1.0 Ci (95% confidence interval of 0.52 – 2.6 Ci) for 1957 - 1959. These results are larger than those reported in HDE (1991), by an average factor of 3. In both studies, Pu-238 was the dominant α-emitting nuclide, contributing 96% to the total α-releases in this study and 87% in HDE (1991).

8.0 REFERENCES

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APPENDIX A

DAILY BETA-MINUS IODINE AND AEROSOL RELEASES FROM THE IDAHO CHEMICAL PROCESSING PLANT AS REPORTED IN THE STACK MONITOR DATA SHEETS (WITH REPORTED IODINE-131 RELEASES)

FEBRUARY 1957 – DECEMBER 1959

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for February 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in February	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	run 1	NA†	0	71,400
2	run 1	NA	0	56,100
3	run 1	NA	0	32,800
4		NA	0	9,590
5	(β-I) procedure	NA	0	24,800
6	incorrect in	NA	0	27,100
7	Feb., March	NA	0	18,400
8		NA	0	20,000
9		NA	0	44,500
10		NA	0	28,900
11		NA	0	26,400
12		NA	0	6,600
13		NA	0	1,900
14		NA	0	2,100
15		NA	0	2,100
16		NA	0	2,300
17		NA	7.1	2,410
18		NA	0	2,000
19		NA	1.4	2,200
20	run 2	NA	38.2	7,000
21	run 2	NA	16	51,600
22		NA	0	10,700
23		NA	0	10,700
24		NA	0	10,700
25		NA	2.8	96,600
26		NA	0	46,800
27		NA	15	27,300
28		NA	0	18,300

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.
† Reported (β-I) releases for February and March 1957 are omitted due to error in the radiochemical procedure.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for March 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in March	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in March	NA†	0	4,840
2		NA	0	15,540
3	(β-I) procedure incorrect	NA	0	13,200
4	in Feb., March	NA	0	10,820
5		NA	0	2,050
6		NA	0	1,360
7		NA	0	1,910
8		NA	0	1,850
9		NA	0	1,235
10		NA	0	824
11		NA	0	1,360
12		NA	0	777
13		NA	0	10,900
14		NA	8.8	6,950
15		NA	0	5,175
16		NA	0	5,175
17		NA	0	3,400
18		NA	0	1,270
19		NA	0	1,200
20		NA	0	523
21		NA	0	705
22		NA	0	412
23		NA	0	470
24		NA	0	1,330
25		NA	0	2,190
26		NA	0	399
27		NA	0	227
28		NA	0	227
29		NA	0	227
30		NA	0	227
31		NA	0	227

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.
† Reported (β-I) releases for February and March 1957 are omitted due to error in the radiochemical procedure.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for April 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in April	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		19.1	0	54
2		11.6	0	28
3		0	0	31
4		133	0	909
5	run 3	35	0	1,787
6	run 3	73.9	0	920
7		57.2	0	671
8		110	0	378
9		47.4	0	4,170
10		41.4	0	529
11		30.9	0	465
12		31.5	0	1,080
13		24	0	4,770
14		90.6	0	3,180
15		21.1	0	4,910
16		70	0	4,460
17		185	0	13,130
18		41.3	0	4,470
19		40	0	3,440
20		17.1	0	6,980
21		33.3	0	7,270
22		27.7	0.9	3,210
23		20	0.7	1,215
24		7	0	291
25		0	0	455
26		5.3	0	843
27		30.9	0	808
28		0.8	0	773
29		18.5	0.4	2,828
30		20	0	1,670

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for May 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in May	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		20	0	1,100
2		18.5	0.3	1,770
3		46.1	0	1,325
4		22.1	0	537
5		29.6	0.9	619
6		26.4	0	565
7		17.5	0	514
8		26.3	0	304
9		10.3	0	294
10		3.5	0.1	200
11		13.86	0.05	146
12		10.97	0	384
13		11.6	0.7	512
14		6	0	541
15		7	0.6	250
16		34	0	475
17		0	0	377
18		4.8	0	236
19	run 4	396	0	654
20	run 4	1,850	0	7,334
21		825	0	2,436
22		471	0.01	8,561
23		25.6	0	5,300
24		1,670	1.4	1,675
25		36	0.6	995
26		124	0.7	2,210
27		144.1	0	1,217
28		72.3	0	1,410
29		61.3	0	825
30		57.3	0	800
31		37.1	0	783

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for February 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in June	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		38.5	0	685
2		45	0	650
3		39.2	0	603
4		36	0	527
5		155	0	447
6		85.2	0	1,130
7		49.6	0	650
8		39.5	0	225
9		25.6	0	168
10		37.1	0	95
11		14.2	0.2	182
12		31.2	0	104
13		40.3	0	73
14		19.4	0	620
15		18.8	0	285
16		36.4	0	285
17		25	0	289
18		14.9	0	249
19		7.2	0	309
20		10.2	0	109
21		4.5	0	113
22		0	0.44	33
23		340	0	28
24	run 5	897	0	2,070
25	run 5	438	0	3,350
26		440	0	264
27		384	0.44	813
28		492	0	86,000
29		497	0	33,200
30		284	0	9,460

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for July 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in July	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in July	32.2	0	4,470
2		231	0	3,195
3		233	0	2,130
4		130	0	4,040
5		146	0	1,250
6		139	0	632
7		101	0.23	812
8		62	0	576
9		60	0.26	372
10		73	0	304
11		56	0.19	254
12		57	0	186
13		45	0	155
14		32	0	132
15		143	0	205
16		196	0.18	3,745
17		37	0	108
18		54	0	52
19		45	0.18	60
20		43	0	61
21		41	0	113
22		13	0	75
23		5	0	68
24		66	0	74
25		78	0	76
26		83	0	51
27		18	0	23
28		44	0	16
29		14	0	16
30		3	0	9
31		26	0.5	16

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for August 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in August	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in August	3	0.1	1
2		0	0	1
3		4	0.2	9
4		0	0.4	7
5		6	0	3
6		9	0	8
7		8	0	6
8		0	0	6
9		0	0	14
10		0	0	3
11		4	0	4
12		1	0	6
13		5	0	5
14		104	0	3
15		12	0.4	2
16		20	0	0
17		15	0	8
18		14	0.2	8
19		2	0.1	8
20		0	0	9
21		2	0	3
22		0	0.1	0
23		0	0	0
24		0	0	0
25		0	0	5
26		0	0	7
27		0	0	3
28		5	0	1
29		2	0	0
30		14	0	6
31		23	0	8

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for September 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in September	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		5	0	24
2		11	0.3	14
3		17	0.05	17
4		2	0	17
5		22	0	2
6		5	1	21
7		24	0	17
8		3	0	22
9		51	0	4
10		323	0	29
11	run 6 - a one day run	3,230	0	63
12		271	0	3,900
13		51	0	4,200
14		126	0	2,560
15		55	0.7	3,690
16		71	1.4	1,810
17		50	0.3	1,730
18		67	0	966
19		42	0	628
20		45	0	953
21		52	0.1	685
22		0	0	1,123
23		25	0	1,550
24		6	0	1,020
25		46	0.05	1,450
26		3	0	1,530
27		32	0.2	327
28		19	0	1,150
29		82	0	1,023
30		42	0	913

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for October 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in October	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		21	0	942
2		1	0	898
3		68	0	19,100
4		112	0	19,840
5		186	0.3	9,900
6		259	0	19,200
7	run 7 - one day run	2,740	0	40,600
8		915	0.8	12,400
9		630	0	9,720
10		645	0.7	4,070
11		673	0	3,740
12		402	0	5,110
13		808	0.5	6,200
14		771	0	9,580
15		573	0	7,550
16		523	0.8	13,680
17		562	0	7,500
18		612	0	2,660
19		388	0	1,900
20		354	1.3	1,450
21	run 8 - one day run	441	0.5	1,535
22		516	0	13,800
23		778	0	25,800
24		664	0	12,800
25		313	0	7,050
26		513	0	2,850
27		433	0	2,050
28		44	0	2,610
29		107	0	3,390
30		376	0.5	3,600
31		920	0	6,220

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for November 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in November	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in November	921	0	15,600
2		587	0	4,320
3		657	0.7	3,520
4		482	0	8,830
5		334	0	7,350
6		495	0	10,100
7		469	0	16,200
8		582	0	31,400
9		457	0	19,600
10		491	0	17,600
11		572	0	23,200
12		315	0	11,150
13		572	0	14,370
14		784	0	7,300
15		612	0	6,560
16		826	0.85	8,360
17		780	0.74	4,530
18		897	0	4,080
19		748	0	2,430
20		843	0	3,240
21		955	0	1,420
22		625	0.6	1,055
23		552	0	1,150
24		624	0	937
25		423	0.2	396
26		526	0	288
27		787	0	254
28		620	0	300
29		885	0	176
30		844	0	125

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for December 1957
(Stack Monitor Datasheets, 1957-1959)*

Day in December	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in December	618	0	155
2		1,080	0	87
3		890	0	269
4		795	2.2	151
5		871	0	171
6		800	0	109
7		532	0	97
8		563	0.9	98
9		525	0	131
10		525	0	339
11		534	0	199
12		360	0.5	121
13		398	0	94
14		281	0	52
15		354	0	68
16		388	0	59
17		310	0	41
18		401	0	42
19		291	0.2	29
20		625	0	9
21		228	0	31
22		286	0	22
23		178	0.2	12
24		191	0	30
25		149	0	13
26		243	0	15
27		318	0	9
28		1,460	0.5	13
29		107	0.3	5
30		256	0	41
31		120	0	0

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for January 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in January	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		170	3.6	30
2		78	0.2	18
3		180	0	12
4		110	0	8
5		192	0.6	65
6	run 9 - one day run	3,000	0.9	3,500
7		2,500	0	4,000
8		2,000	0.5	2,600
9		888	0	1,780
10		846	0	2,460
11		558	0.5	2,520
12		342	0	2,260
13		803	0	1,880
14		498	0	1,045
15		518	0	550
16		753	0.5	930
17		630	0	677
18		376	1.9	413
19		365	0.5	398
20		593	0	138
21		458	0	76
22		272	0	19
23		224	0	15
24		417	0	108
25		326	0	512
26		1,100	0	456
27		783	0	773
28		567	0.5	700
29		430	0	913
30		643	0	805
31		718	0	845

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for February 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in February	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		590	0.1	601
2		596	0	511
3		638	0	726
4		625	0	446
5		495	0	470
6		346	0	292
7		580	0	290
8		602	0	293
9		894	0	376
10		520	0	457
11		625	0	352
12	run 10 - one day run	2,170	0	3,000
13		1,420	0.5	7,430
14		1,240	0	5,540
15		1,110	0.1	6,170
16		1,230	0.2	5,010
17		1,140	0	2,330
18		1,096	0	1,470
19		968	0	1,580
20		856	0	15,280
21		780	0	694
22		828	0	657
23		620	0	627
24		675	0	630
25		616	0	472
26		721	0	392
27		633	0	331
28		670	0	18,900

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for March 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in March	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		828	0	48,200
2		508	0	14,700
3		625	0	11,030
4		855	0	3,030
5		978	0	2,000
6		458	0	927
7		667	0	1,340
8		800	0	1,000
9		1,050	0	740
10		1,500	0.4	557
11		1,070	0	258
12		513	0	258
13	run 11	1,000	0.1	1,290
14	run 11	557	0.1	7,400
15		302	0.1	2,960
16		323	0.1	2,480
17		822	0.3	1,540
18		797	0.2	1,510
19		576	0.8	2,350
20		1,040	0	4,220
21		310	0	3,200
22		877	0	1,700
23		810	0	2,520
24		364	0	2,060
25		372	0	1,750
26		344	0	1,880
27		270	0.5	2,260
28		314	0	2,420
29		279	0	1,310
30		368	0	1,230
31		186	0	1,590

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for April 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in April	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		193	0	1,725
2		308	0	2,020
3		112	0	755
4		315	0	595
5		63	0	486
6		145	0	1,120
7		323	0	683
8		332	0	823
9		265	0	312
10		223	0	363
11		110	0	280
12		65	0.7	260
13		52	0.8	170
14		146	0	195
15		65	0	150
16	run 12 - one day run	1,650	1.3	3,375
17		1,300	0	6,560
18		1,110	0	7,120
19		774	0	3,420
20		610	0	2,490
21		525	0	2,380
22		450	0	995
23		445	0	1,410
24		352	0	1,700
25		496	0.3	1,260
26		397	0	993
27		340	0.1	956
28		425	0	2,000
29		276	0	276
30	run 13	2,280	0.2	4,220

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for May 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in May	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	run 13	2,220	0	5,850
2		1,540	0.3	3,180
3		1,240	0.7	1,830
4		1,120	2.3	1,980
5		910	0	2,250
6		910	0	3,620
7		750	0	1,960
8		685	0.2	1,720
9		825	0.4	1,750
10		73	0.3	678
11		330	0	567
12		1,130	0.4	18,600
13		863	0.2	39,300
14		394	0.2	20,500
15		475	0.6	12,900
16		800	0	10,800
17		388	0	8,780
18		580	0	7,840
19		657	0	6,000
20		885	0	5,480
21		990	1.1	2,900
22		1,200	0	3,140
23		925	0.3	1,780
24		658	0.6	1,500
25		330	0	1,300
26		390	0	3,320
27		355	0	2,870
28	run 14 - one day run	17,500	0	49,500
29		6,330	0.3	33,400
30		2,860	1.2	14,000
31		1,160	0	6,350

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for June 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in June	Comment	β-I mCi/day	a mCi/day	I-131 mCi/day
1		750	0	7,900
2	run 15 - one day run	1,040	0	7,100
3		650	0.5	6,300
4		650	0	6,200
5		1,340	1.4	11,700
6		970	1.7	9,000
7		790	0.2	6,500
8		690	0.2	2,400
9		1,900	1.9	18,400
10		1,060	0.2	34,200
11		590	4.8	32,500
12		770	0	25,500
13		690	0	13,400
14		680	0	12,700
15		330	0	6,600
16		300	0	5,300
17		350	0	1,400
18		570	1.1	1,500
19		1,150	0	1,000
20		730	0	630
21		550	0	110
22		1,060	0	216
23		830	0	190
24		1,110	0	300
25		755	0	440
26		720	0	225
27		800	0	260
28		990	0.2	76
29		940	0	76
30		710	0	50

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for July 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in July	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in July	680	0	54
2		880	1	67
3		959	0	567
4		732	0.5	17
5		740	0.8	42
6		920	0.4	67
7		770	0.2	49
8		770	0.5	58
9		570	0.2	96
10		680	0	38
11		1,390	0	52
12		730	0	37
13		820	0	24
14		1,190	0	16
15		970	0.6	54
16		910	1.4	32
17		1,910	0	38
18		1,340	0	47
19		860	0	19
20		510	0.3	4
21		86	0.1	26
22		122	0	31
23		830	0	12
24		1,100	0.1	3
25		620	0	8
26		610	0	9
27		630	0.3	6
28		710	0.5	0
29		820	0	3
30		700	0	7
31		570	0.2	12

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for August 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in August	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	First month with	410	0.3	12
2	charcoal absorber	400	0	8
3		770	0	9
4		1,090	0.2	9
5		1,450	0	6
6	run 16 - one day run	1,580	0	270
7		3,000	1.3	310
8		2,450	0	290
9		1,290	0	240
10		1,000	0	150
11		4,020	0	12,800
12		1,570	3.1	13,600
13	run 17 - one day run	2,370	0	8,300
14		3,000	0	6,100
15		2,100	0	4,670
16		2,300	0	3,190
17		2,060	0	2,770
18		1,810	0	1,090
19		1,950	0	1,450
20		2,710	0	820
21		900	0	990
22		1,330	0.5	1,000
23		1,070	0	730
24		1,470	0	260
25		1,720	0	480
26		1,380	0	170
27		1,820	0	300
28		1,120	0	3,740
29		1,860	0	12,600
30		1,120	0.3	1,170
31		1,140	0	990

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for September 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in September	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in September	470	0	1,170
2		2,668	0	1,000
3		1,730	0.2	470
4		1,420	0	2,000
5		1,150	0	3,730
6		1,410	0	3,150
7		1,240	0.4	1,850
8		3,090	0	2,010
9		850	0	460
10		1,750	0	1,950
11		2,740	0	840
12		1,980	0	890
13		1,580	0	320
14		1,500	0	100
15		2,110	0	550
16		2,290	0	570
17		3,250	0	630
18		1,300	0	1,060
19		1,880	0	970
20		940	0	250
21		1,030	0	150
22		840	0	100
23		720	0	30
24		770	0	10
25		690	0.3	40
26		1,030	3.9	54
27		910	0	16
28		1,260	1.2	63
29		1,200	0	46
30		520	0	13

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for October 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in October	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	run 18 - one day run	22,430	0	16,300
2		3,600	0	10,000
3		1,790	0	5,100
4		2,010	0	2,240
5		860	0	750
6		1,630	0	1,590
7		2,050	0	820
8		1,780	0	720
9		1,290	0	560
10		1,130	0	1,210
11		1,180	0	630
12		1,910	0	900
13		1,540	0	1,700
14		1,900	0	800
15		2,050	0	8,690
16		2,130	0	7,000
17		2,710	0	4,570
18		1,400	0	2,460
19		3,360	0	1,650
20		2,750	0	1,760
21		2,350	0	1,120
22	run 19 - one day run	4,770	0	4,390
23		3,680	0	10,200
24		4,200	0	8,100
25		1,790	0.2	4,230
26		1,480	0	2,330
27		850	0.5	4,660
28		1,630	0	2,110
29		2,700	0	1,300
30		1,430	0	1,170
31		860	0	620

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for November 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in November	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		1,050	0.4	450
2		960	0	560
3		500	0	450
4		700	0	540
5		690	0	160
6	No run 20	450	0	310
7	numbering error	470	0	830
8		450	0	1,010
9		500	0	900
10		890	0	860
11		540	0	460
12	run 21 - one day run	2,490	0	3,510
13		2,220	0	4,080
14		990	0	9,540
15		690	0	3,800
16		2,680	0	990
17		3,000	0	1,160
18		1,250	0	420
19		11,480	0	1,530
20		3,810	0.1	1,030
21		1,660	0.9	730
22		830	0	250
23		540	0	180
24		2,000	0.3	220
25		720	0	190
26		440	0	40
27		1,170	0	80
28		750	0	110
29		1,550	0	480
30		950	0	160

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for December 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in December	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in December	820	0	190
2		360	0	140
3		310	0	180
4		320	0	130
5		1,000	0	130
6		980	0	100
7		580	0	90
8		900	0	90
9		580	0	70
10		3,620	0	770
11		800	0	170
12		1,150	0	60
13		540	0	30
14		660	0	30
15		210	0	30
16		790	0	150
17		1,160	0	20
18		440	0	10
19		710	0.4	160
20		860	0	160
21		250	0	110
22		370	0	80
23		690	0	250
24		170	0	110
25		370	0	130
26		170	0	60
27		2,330	0	190
28		660	0	30
29		1,590	0	140
30		260	0	0
31		200	0	5

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for January 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in January	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	No runs in January	110	0	6
2		100	0	1
3		510	0	1
4		1,980	0	4
5		1,420	0	10
6		320	0	10
7		260	0	13
8		160	0	2
9		110	0.4	8
10		100	0	11
11		110	0	16
12		90	0	18
13		60	0	53
14		20	0	0
15		150	0	0
16		100	0	9
17		70	0	2
18		250	0	8
19		10	0	0
20		290	0	12
21		280	0	1
22		200	0	9
23		320	0	5
24		230	0	7
25		130	0	8
26		140	0	5
27		90	0	0
28		70	0	13
29		150	0	3
30		140	0	10
31		110	0	3

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for February 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in February	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		300	0	6
2		120	0	4
3		190	0	10
4	run 22 - one day run	3,180	0	6,440
5		2,950	0	9,570
6		2,920	0	31,500
7		2,030	0	20,300
8		210	0	7,830
9		280	0	2,250
10		160	0	2,220
11		50	0	1,420
12		500	0	1,860
13		440	0	1,750
14		350	0	370
15		740	0	1,930
16		410	0	160
17		220	0	1,350
18		400	0	7,540
19		950	0	5,940
20		150	0	1,360
21		70	0	70
22		60	0	460
23		50	0	280
24		130	0	180
25	run 23 - one day run	150	0	450
26		2,410	0	2,490
27		510	0	2,230
28		280	0	1,680

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for March 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in March	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		80	0	420
2		90	0	250
3		70	0.1	160
4		210	0	430
5		140	0	320
6		140	0	190
7		60	0	130
8		150	0	100
9		140	0.4	250
10		300	0	420
11		250	0	1,120
12		270	0	1,090
13		200	0	1,200
14		200	0	560
15		290	0	330
16		290	0	400
17		140	0	150
18	run 24 - one day run	480	0	460
19		2,420	0	13,000
20		1,380	0	12,600
21		450	0	4,700
22		350	0	1,650
23		310	0	1,390
24		270	0	1,550
25		360	0	3,090
26		430	0	360
27		200	0	210
28		210	0	250
29		160	0	100
30		110	0.1	190
31		220	0	140

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for April 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in April	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		150	0	210
2		150	0	170
3		80	0	80
4		30	0	90
5		100	0	70
6		80	0	90
7		10	0	90
8	run 25 - one day run	220	0	150
9		80	0	140
10		40	0	140
11		30	0	190
12		40	0	80
13		110	0	100
14		60	0	50
15		150	0	320
16		70	0	1,520
17		90	0	760
18		30	0	250
19		270	0	310
20		900	0	100
21		720	0	180
22		530	0	50
23		710	0	60
24		1,170	0.1	90
25		1,520	0	90
26		1,150	0	60
27		1,310	0.1	40
28		1,770	0.1	60
29	run 26 - one day run	3,420	0	1,030
30		1,500	0	1,200

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for May 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in May	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		1,780	0.1	320
2		880	2.6	120
3		1,340	0.6	120
4		1,320	0	60
5		1,000	0	100
6		1,490	0	40
7		1,150	0	50
8		1,310	0	60
9		1,020	0	30
10		1,020	0	30
11		650	0	20
12		950	1.6	20
13		1,750	0	30
14		1,250	0.1	10
15		1,150	0.4	40
16		1,700	0.6	60
17		1,640	0	30
18		970	1.1	20
19	run 27 - one day run	1,390	0	40
20		2,560	1.3	910
21		1,480	0	310
22		1,620	0	110
23		1,140	0.1	90
24		810	0.2	100
25		1,120	0	60
26		650	0	50
27		770	0	70
28		540	0	80
29		570	0	50
30		450	0	20
31		530	0	40

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for June 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in June	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		660	0	30
2		815	0	0
3		900	0	20
4		670	0	250
5		1,020	0	50
6		1,050	0	20
7		850	1.3	0
8		1,280	0	20
9		1,340	0	0
10	run 28 - one day run	1,800	0	650
11		1,700	0.5	240
12		1,490	0	140
13		1,200	0.2	40
14		270	0	50
15		1,550	0	20
16		2,310	0	10
17		1,280	0.4	250
18		2,030	0	200
19		1,950	0	50
20		1,530	0	30
21		1,220	0	20
22		890	0	20
23		850	0	40
24		600	0	60
25		1,220	0	50
26		990	0	30
27		290	0	60
28		380	0	20
29		560	0	20
30		310	0	20

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for July 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in July	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		1,040	0	0
2		640	0	40
3		280	0	10
4		290	0	30
5		590	0	10
6	run 29	420	0	250
7	run 29	1,140	0	2,560
8		710	0	1,180
9		930	5.5	280
10		600	4	160
11		670	2.6	60
12		500	0.2	30
13		460	0	10
14		290	1.3	90
15		730	20.4	220
16		350	0	190
17		600	0.2	80
18		280	0	70
19		290	0	40
20		380	0	90
21	run 30	550	0	1,100
22	run 30	1,000	0.7	750
23		300	0	750
24		460	0	480
25		1,380	0	1,270
26		230	0	120
27		230	0	60
28		210	0	30
29		120	0	30
30		280	0	40
31		160	0	40

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for August 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in August	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		250	0	60
2		300	0	30
3		1,280	0	430
4		420	0	340
5		470	0	340
6		200	0	180
7		230	0	60
8		240	0	100
9		250	0	80
10		10	0	70
11	run 31	670	0	500
12	run 31	760	0	190
13		1,130	0.8	180
14		660	0	180
15		360	0.8	40
16		470	0.4	80
17		380	0	80
18		170	0	110
19		130	0	90
20		3,420	0	20
21		90	0	30
22		100	0.4	10
23		100	0	30
24		60	0	290
25		80	0	80
26		120	0	90
27		110	0	20
28		190	0	50
29		270	0	10
30		210	0	40
31		130	0	10

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for September 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in September	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	run 32	550	0	420
2	run 32	260	0	280
3		270	0	200
4		240	0	100
5		200	0	20
6		170	0	40
7		150	0.21	30
8		220	0	340
9		200	0	690
10		200	0	960
11		200	0	320
12		160	0	130
13		190	0	90
14		120	0	70
15		90	0	30
16		110	0	80
17		290	0	280
18		100	0	140
19		100	0	160
20		110	0	80
21		120	0	30
22	run 33	290	0	270
23	run 33	140	0	190
24		390	0	130
25		250	0	100
26		260	0	90
27		230	0	690
28		290	0	960
29		220	0	850
30		280	0	300

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for October 1958
(Stack Monitor Datasheets, 1957-1959)*

Day in October	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		160	0	200
2		210	0	90
3		970	0	40
4		90	0	20
5		90	0	30
6		170	0	460
7		190	0	180
8		100	0	200
9		130	0	50
10		150	0	70
11		90	0	70
12		130	0.19	60
13	run 34	3,860	0	60
14	run 34	630	0	570
15		600	0	400
16	ICPP Criticality Accident	8,170	0	3,730
17		4,930	0	2,440
18		2,860	0	970
19		1,850	0	1,010
20		1,400	0	1,150
21		520	0	940
22		960	0	870
23		710	0	180
24		630	0	150
25		460	0	90
26		600	0	40
27		410	0	100
28		470	0	120
29		360	0	330
30		280	0	170
31		310	0	240

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for November 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in November	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1		200	0	100
2		130	0	140
3		190	0	140
4		50	0	70
5	run 35	890	0	800
6	run 35	670	0	1,830
7		270	0	4,470
8		140	0	160
9		260	0	270
10		180	0	300
11		210	0	490
12		780	0	60
13		1,440	2.72	930
14		1,590	5.95	150
15		620	1.32	550
16		270	0.1	330
17		120	0.22	320
18		190	0	390
19		110	0	270
20		170	0	120
21		170	0	300
22		340	0	310
23		100	0	540
24		350	0	160
25		70	0	70
26		70	0	20
27		60	0	30
28		60	1.15	10
29		50	0	10
30	run 36	50	0	20

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

Table A.1 Reported daily beta-minus iodine, alpha, and iodine-131 releases from the Idaho Chemical Processing Plant for December 1959
(Stack Monitor Datasheets, 1957-1959)*

Day in December	Comment	β-I mCi/day	α mCi/day	I-131 mCi/day
1	run 36	70	0	60
2		70	0	110
3		50	0	50
4		50	0	50
5		110	0	20
6		260	0	20
7		60	0	10
8		140	0	20
9		330	0	10
10		200	0	10
11		140	0	10
12		440	0	10
13		280	0	20
14		330	0.22	20
15	run 37	960	0	200
16	run 37	410	0.56	240
17		210	0	160
18		470	0	210
19		200	0	140
20		280	0	100
21		220	0	60
22		360	0	70
23		400	0	60
24		350	0	40
25		560	0	40
26		160	0	30
27		240	0.68	10
28		80	0	10
29		50	0	10
30		80	0	20
31		90	0	0

* All reported (β-I) and α releases were based on an assumed 100% capture efficiency of aerosols in the stack sampler.

APPENDIX B

APPROACH FOR DERIVING RELEASES OF RADIONUCLIDES ATTACHED TO AEROSOLS

APPENDIX B: APPROACH FOR DERIVING RELEASES OF RADIONUCLIDES ATTACHED TO AEROSOLS

This approach is designed to account for the sampler efficiency and for the decay of short-lived radionuclides, both during sampling and during the waiting time between the end of the sampling period and the beginning of the sample counting.

The following information is available:

- Reported β-I daily releases (R_m; Appendix A), obtained from the Stack Monitor Datasheets. These releases are obtained from the measured β-I activity in the sample of air collected from stack, corrected for the differences in the stack flow rate (Q_{stk}) and sampling line flow rate ($Q_{sampler}$). As discussed in Chapter 4, the reported daily releases are based on an assumed 100% sampler efficiency, and they are not corrected for the decay of short-lived radionuclides, both during sampling and during the waiting time between the end of the sampling period and the beginning of the sample counting.

- The activity of each radionuclide, following the dissolution in the RaLa processing tanks ($A_{d,i}$; i = index for the radionuclides; in Ci), for each of the 100 days after removal from the reactor of a "typical" MTR fuel element. The list of radionuclides does not include gaseous nuclides (i.e., iodine, bromine, xenon, and krypton), which should not have contributed significantly to the β-I measurements.

- The number of beta particles and electrons with an average energy greater than 25 keV, emitted on average from each nuclear disintegration of a given radionuclide (Y_i).

In a given day after a RaLa run, a radionuclide i with an activity $A_{d,i}$ in the RaLa processing tanks will produce a concentration in the stack airflow $C_{a,i}$ (Ci m^{-3}) which is proportional to the activity $A_{d,i}$.

$$C_{a,i}(t_n) = b \cdot A_{d,i}(t_n) \tag{B-1}$$

The principal assumption is that the proportionality parameter "b" is the same for all radionuclides that attach to particles. That is, all radionuclides are assumed to have more or less the same affinity to attach to aerosols. The time (t_n) represents the number of days from the beginning of the RaLa run.

Our purpose is to determine the activity released into the atmosphere for each radionuclide i ($R_{cor,i}$, in Ci), corrected for the reduced sampler efficiency and for the decay of short-lived radionuclides, both during sampling and during the waiting time between the end of the sampling period and the beginning of the sample counting.

The corrected releases ($R_{cor,\,i}$, in Ci) are calculated for every day (t_n) during the RaLa release, given that, during that day, the air in the stack was sampled for 24 hours (i.e., the sampling period t_s = 24 hours = 1 day).

$$R_{cor,\,i} = C_{a,i} \cdot Q_{stk} \cdot t_s = b \cdot A_{d,\,i} \cdot Q_{stk} \cdot t_s \qquad \text{(B-2)}$$

where

$C_{a\,,i}$	=	concentration of radionuclide *i* in the stack airflow (Ci m^{-3})
Q_{stk}	=	stack flow rate (m^3 d^{-1})
t_s	=	sampling period (d)
b	=	proportionality constant (m^{-3}) between the activity $A_{d,i}$ in the RaLa processing tanks (Ci) and the concentration in the stack airflow $C_{a,i}$ (Ci m^{-3})

The reported releases were made by sampling the air going out of the stack, drawing air at flow rate $Q_{sampler}$. The releases reported in the datasheet have been corrected for the differences between the Q_{stk} and $Q_{sampler}$, so that they represent an amount released and not the amount sampled.

To relate the reported releases (R_m) to the concentration in the air flow, the following mass-balance equation can be written for the number of atoms (N_i) of radionuclide *i* accumulating in the sampler:

$$\frac{dN_i}{dt} = \left(\frac{C_{a,i}}{\lambda_i}\right) \cdot Q_{sampler} \cdot f - \lambda_i N_i \qquad \text{(B-3)}$$

where

N_i	=	number of atoms of radionuclide *i* accumulating in the sampler (unitless)
$C_{a\,,i}$	=	concentration of radionuclide *i* in the stack airflow (Ci m^{-3})
$Q_{sampler}$	=	flow rate in the sampling line (m^3 d^{-1})
f	=	efficiency of the sampler in collecting particles (unitless)
$\lambda_{,i}$	=	radioactive decay constant for radionuclide *i* (d^{-1})

Assuming the release rate is constant during the sampling period (t_s), the activity present in the sample at the end of the sampling period ($A_{s,i}$) is:

$$A_{s,i}(t_s) = \lambda_i N_i = C_{a,i} \cdot Q_{sampler} \cdot f \cdot \frac{1 - \exp(-\lambda_i t_s)}{\lambda_i} \qquad \text{(B-4)}$$

where all quantities are defined above and

$A_{s\,,i}$	=	activity in the sample at the end of the sampling period (Ci)

The contribution of radionuclide *i* to the number of β-I counts registered on the detector is determined given the following:

- Only a fraction Y_i of the decays produce beta particles or electrons with an average energy greater than 25 keV (Appendix D)
- The activity decreases during the waiting time between the end of the sampling and the beginning of measurement (t_w).

$$A_{m,i} = b \cdot A_{d,i} \cdot Y_i \cdot Q_{sampler} \cdot f \cdot \frac{1-\exp(-\lambda_i t_s)}{\lambda_i} \cdot \exp(-\lambda_i t_w) \qquad \text{(B-5)}$$

where all quantities are defined above and

$A_{m,i}$	=	the activity of radionuclide *i* (Ci) that contributes to the total activity of measured by the detector.
t_w	=	waiting time between the end of the sampling and the beginning of measurement (d)

In the above equation the concentration in the airflow was replaced by its relationship with the activity in the dissolver (see Equation B-1).

The total activity measured (A_m) is the sum of the contributions from each radionuclide ($A_{m,i}$).

$$A_m = \sum_{i=1}^{N} A_{m,i}$$

$$= b \cdot Q_{sampler} \cdot f \cdot t_s \cdot \sum_{i=1}^{N} A_{d,i} \cdot Y_i \cdot \frac{1-\exp(-\lambda_i t_s)}{\lambda_i t_s} \cdot \exp(-\lambda_i t_w) \qquad \text{(B-6)}$$

$$= b \cdot Q_{sampler} \cdot f \cdot t_s \cdot S$$

where all quantities are defined above and

S	=	decay-corrected and sample-efficiency-corrected activity in the dissolver, summed over all radionuclides (in Ci)
A_m	=	the total activity of measured by the detector (Ci)

The activities $A_{d,i}$, the fractions Y_i , and the radioactive decay constant λ_i are known. The sampling time is also known (t_s was generally 24 hours). Based on the few available records for April 1957, the average waiting time was determined to be about t_w = 14 hours (with a range 3 – 48 hours). Thus, the activity S can be calculated with available information for any given day (t_n).

The reported β-I releases (R_m) were obtained by multiplying the total activity measured (A_m) by the ratio of the stack to sampler flow rates (F_{flow}), so that the product of ($Q_{sampler} \times F_{flow}$) is equal to the stack flow rate (Q_{stk}).

$$R_m = A_m \cdot F_{flow} = b \cdot Q_{stk} \cdot f \cdot t_s \cdot S \qquad \text{(B-7)}$$

where all quantities are defined above and

F_{flow} = the ratio of the stack and sampler flow rates ($Q_{stk}/Q_{sampler}$; unitless).
Q_{stk} = stack flow rate ($m^3\ d^{-1}$)
$Q_{sampler}$ = flow rate in the sampling line ($m^3\ d^{-1}$)

The proportionality constant b between the activity $A_{d,i}$ in the dissolver (Ci) and the concentration in the stack airflow $C_{a,i}$ (Ci m^{-3}) is given by:

$$b = \frac{R_m}{Q_{stk} \cdot f \cdot t_s \cdot S} \qquad \text{(B-8)}$$

Using Equations B-2 and B-8, the amount of radionuclide i released during the sampling period (corrected for the decay of short-lived radionuclides during sampling, and during the waiting time between the end of the sampling period and the beginning of the sample counting and corrected for the reduced sampler efficiency) can be determined as a function of the reported β-I releases (R_m).

$$R_{cor,i} = a \cdot A_{d,i} \cdot Q_{stk} \cdot t_s = A_{d,i} \cdot \left(\frac{R_m}{f} \cdot \frac{1}{S} \right) \qquad \text{(B-9)}$$

The above equation estimates releases for all radionuclides, including those that have no contribution to the measured β-I daily releases. For instance, ^{106}Ru is present in the dissolver and is released into the atmosphere, but due to the weak beta particles produces no contribution to the measured β-I daily releases (i.e., $Y_{Ru\text{-}106} = 0$). The amount released ($R_{Ru=106}$) does not depend directly on Y_i. It depends on the activity in the dissolver $A_{d,i}$, the sampler efficiency f, and the activity S (which is a function of the Y_i for all radionuclides).

In principle, Equation B-9 can be used to determine releases of any radionuclides, including gases (e.g., iodine, xenons, kryptons, bromines), as long as the activity in the dissolver ($A_{d,i}$) can be determined for that radionuclide in the day when the measurement (R_m) was taken. For the radionuclides that can attach to particles, the activity in the dissolver can be determined using ORIGEN computer code, because the loss of radioactivity (*via* emission as aerosols) is small compared to the inventory in the dissolver. For gases, however, the majority of the radioactivity is lost shortly after dissolution, so the activity in the dissolver at a given time after dissolution is hard to predict.

Table B.1 presents an example calculation for the first day of RaLa Run #6 (September 1, 1957), while Table B.2 gives the estimated releases during day 15 (Feb 18, 1959) of RaLa Run #22.

One should note that the decay correction has a larger effect for short times after the beginning of a RaLa run. However, for some radionuclides (e.g., ^{99m}Tc), the decay correction is important for any time after exposure.

Table B.1 Estimated releases during the first day of RaLa run #6 on September 11, 1957, when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 3,230 mCi

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
La-140	712	849	40.272	hours
Pr-143	637	781	13.56	days
Ba-140	757	781	12.74	days
Ce-141	548	545	32.501	days
Mo-99	448	538	66	hours
Tc-99m	47	519	6.02	hours
Te-132	435	423	78.2	hours
Zr-95	321	393	63.98	days
Y-91	314	385	58.51	days
Sr-89	274	336	50.5	days
Nd-147	365	276	10.98	days
Ce-143	252	256	33	hours
Ru-103	208	252	39.28	days
Rh-103m	167	227	56.12	minutes
Nb-95	133	163	35.15	days
U-237	248	136	6.75	days
Pm-149	97	118	53.08	hours
Pr-144	75	92	17.28	minutes
Ce-144	87	92	284.3	days
Nb-97	50	61	72.1	minutes
Zr-97	50	61	16.9	hours
Nb-97m	1.0	58	60	seconds
Rh-105	27	34	35.3	hours
Sm-153	38	29	46.7	hours
Pm-148	19	23	5.37	days
Te-127	14	17	9.35	hours
Sb-127	15	17	3.85	days
Te-131m	15	15	30	hours
Np-239	28	15	2.335	days
Pm-151	14	14	28.4	hours
Y-93	7.3	9.0	10.1	hours

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

Table B.1 Estimated releases during the first day of RaLa run #6 on September 11, 1957, when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 3,230 mCi - continued

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
Te-129m	5.4	6.6	33.6	days
Pm-147	5.1	6.3	2.6234	years
Sr-91	4.9	6.0	9.5	hours
Np-238	7.2	5.8	2.117	days
Eu-156	6.1	5.4	15.19	days
Rh-106	4.3	5.3	29.9	seconds
Ru-106	0.0	5.3	368.2	days
Te-129	4.1	4.3	69.6	minutes
Y-91m	0.2	3.8	49.71	minutes
Te-131	3.3	3.4	25	minutes
Cs-137	2.3	2.9	30	years
Sr-90	2.3	2.8	29.12	years
Y-90	2.3	2.8	64	hours
Ba-137m	0.2	2.7	2.552	minutes
Nb-95m	1.6	2.6	86.6	hours
Ag-111	1.8	2.2	7.45	days
Cs-136	1.8	1.7	13.1	days
Sn-125	1.2	1.5	9.64	days
Pm-148m	1.2	1.3	41.3	days
Cs-134	0.78	1.3	2.062	years
Pr-144m	0.62	1.1	7.2	minutes
In-115m	0.42	0.94	4.486	hours
Cd-115	0.71	0.86	53.46	hours
Te-127m	0.68	0.81	109	days
Pu-241	3.1E-07	6.0E-03	14.4	years
Pu-238	5.4E-04	3.8E-03	87.74	years
Am-242	4.8E-05	5.7E-05	16.02	hours
Pu-239	3.4E-06	5.3E-05	24065	years
Np-236m	2.4E-05	5.0E-05	22.5	hours
Cm-242	5.0E-06	3.9E-05	162.8	days
Pu-240	4.5E-06	3.3E-05	6537	years

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

Table B.1 Estimated releases during the first day of RaLa run #6 on September 11, 1957, when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 3,230 mCi - continued

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
U-240	2.5E-05	2.3E-05	14.1	hours
U-236	2.8E-06	1.3E-05	23415000	years
U-234	2.2E-06	9.9E-06	244500	years
Th-231	9.0E-06	5.2E-06	25.52	hours
U-235	1.9E-06	4.8E-06	7.04E+08	years
Np-237	2.6E-06	2.8E-06	2140000	years
Pu-236	4.1E-07	1.6E-06	2.851	years
Pu-243	1.0E-06	1.1E-06	4.956	hours
Cm-244	5.9E-08	1.1E-06	18.11	years
Pu-237	7.0E-08	9.8E-07	45.3	days
Pa-233	1.3E-06	8.5E-07	27	days
Pa-232	1.5E-06	7.9E-07	1.31	days
Am-244	1.4E-06	6.2E-07	10.1	hours
Am-241	1.8E-07	3.1E-07	432.2	years
U-238	1.4E-08	7.7E-08	4.47E+09	years
Th-234	4.6E-08	6.1E-08	24.19	days
Pa-234m	5.0E-08	6.1E-08	1.17	minutes
Am-243	1.1E-08	4.4E-08	7380	years
Np-235	6.7E-10	2.6E-08	396.1	days
Pu-242	2.0E-09	1.8E-08	376300	years
Total	**6460.0‡**	**7594.5**		

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

‡ The total release (6460 mCi) is twice the release reported in the Stack Monitor Datasheets (3230 mCi) because the sampler efficiency was assumed to be 50%.

Table B.2 Estimated releases during the day 15 (February 18, 1959) of RaLa run #22 (February 4, 1959) when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 400 mCi

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
La-140	90	102	40.272	hours
Ce-141	104	98	32.501	days
Pr-143	83	96	13.56	days
Ba-140	91	89	12.74	days
Zr-95	71	82	63.98	days
Y-91	68	79	58.51	days
Sr-89	58	67	50.5	days
Nb-95	44	51	35.15	days
Ru-103	42	48	39.28	days
Rh-103m	34	43	56.12	minutes
Nd-147	39	28	10.98	days
Pr-144	19	22	17.28	minutes
Ce-144	22	22	284.3	days
U-237	15	7.8	6.75	days
Te-132	5.7	5.2	78.2	hours
Mo-99	3.4	3.8	66	hours
Tc-99m	0.4	3.7	6.02	hours
Pm-147	1.7	2.0	2.6234	years
Rh-106	1.1	1.3	29.9	seconds
Ru-106	0.0	1.3	368.2	days
Te-129m	1.0	1.2	33.6	days
Pm-148	0.81	0.94	5.37	days
Te-129	0.78	0.78	69.6	minutes
Eu-156	0.82	0.70	15.19	days
Cs-137	0.60	0.70	30	years
Y-90	0.58	0.67	64	hours
Sr-90	0.58	0.67	29.12	years
Ba-137m	0.063	0.66	2.552	minutes
Nb-95m	0.39	0.60	86.6	hours
Te-127	0.44	0.51	9.35	hours
Pm-149	0.31	0.36	53.08	hours

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

Table B.2 Estimated releases during the day 15 (February 18, 1959) of RaLa run #22 (February 4, 1959) when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 400 mCi – continued

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
Sb-127	0.30	0.33	3.85	days
Cs-134	0.20	0.31	2.06	years
Pr-144m	0.15	0.26	7.2	minutes
Pm-148m	0.25	0.25	41.3	days
Te-127m	0.17	0.20	109	days
Cs-136	0.22	0.19	13.1	days
Ag-111	0.13	0.15	7.45	days
Sn-125	0.11	0.13	9.64	days
Np-239	0.12	0.059	2.335	days
Np-238	1.9E-02	1.4E-02	2.117	days
Pu-241	8.1E-08	1.4E-03	14.4	years
Pu-238	1.5E-04	1.0E-03	87.74	years
Pu-239	9.4E-07	1.4E-05	24065	years
Cm-242	1.2E-06	8.9E-06	162.8	days
Pu-240	1.2E-06	8.1E-06	6537	years
U-236	7.1E-07	3.2E-06	2.34E+07	years
U-234	5.8E-07	2.4E-06	2.45E+05	years
Th-231	2.1E-06	1.2E-06	25.52	hours
U-235	5.0E-07	1.2E-06	7.04E+08	years
Np-237	8.8E-07	9.0E-07	2.14E+06	years
Pa-233	6.1E-07	3.9E-07	27	days
Pu-236	1.1E-07	3.8E-07	2.851	years
Cm-244	1.5E-08	2.6E-07	18.11	years
Pu-237	1.5E-08	1.9E-07	45.3	days
Am-241	1.0E-07	1.6E-07	432.2	years
U-238	3.7E-09	1.9E-08	4.47E+09	years
Th-234	1.3E-08	1.6E-08	24.19	days
Pa-234m	1.4E-08	1.6E-08	1.17	minutes
Am-243	2.9E-09	1.1E-08	7380	years
Np-235	1.7E-10	6.1E-09	396.1	days
Pu-242	5.1E-10	4.3E-09	376300	years

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

Table B.2 Estimated releases during the day 15 (February 18, 1959) of RaLa run #22 (February 4, 1959) when the beta-minus iodine release reported in the stack monitor datasheets was R_m = 400 mCi - Continued

Radionuclide	Activity Released: No decay correction* mCi/day	Activity Released: With decay correction† mCi/day	Half-life $T_{1/2}$	Units
Am-242m	2.0E-09	2.3E-09	152	years
Am-242	2.0E-09	2.3E-09	16.02	hours
U-232	4.2E-10	1.5E-09	72	years
Cm-243	1.1E-09	9.7E-10	28.5	years
Total	**800‡**	**861.5**		

* Estimated by ignoring the decay corrections as follows: $R_i = \frac{1}{f} \cdot \frac{A_{d,i} \cdot Y_i}{\sum_{i=1}^{N} A_{d,i} \cdot Y} \cdot R_m$.

† Estimated Equation B-9 in the text.

‡ The total releases (800 mCi) is twice the release reported in the Stack Monitor Datasheets (400 mCi) because the sampler efficiency was assumed to be 50%.

APPENDIX C

BETA-MINUS IODINE ACTIVITY OF SOLID RADIONUCLIDES IN MATERIAL TESTING REACTOR ELEMENTS AND PRODUCTION DURING CRITICALITY ACCIDENT

APPENDIX C: BETA-MINUS IODINE ACTIVITY OF SOLID RADIONUCLIDES IN MATERIAL TESTING REACTOR ELEMENTS AND PRODUCTION DURING CRITICALITY ACCIDENT

The tables in this Appendix give the composition of the solid fission products and actinides contributing to the (β-I) reading each day after the irradiation (for the normal RaLa runs) and each day after the criticality accident (October 16, 1959). The table headers are described below.

For the normal RaLa runs, the tables are given starting with day 3 after irradiation, because dissolution started after a minimum fuel-element cooling time of 2 days.

Day N after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution to Release %

For the October 1959 criticality accident, the tables are given starting with day 1 after the criticality event.

Day N after the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution to Release %

The tables contain the following columns:

NUCLIDE—The ORIGEN2 nuclide list of a 2-day cooled "typical" MTR element, less the iodine, bromine, xenon, and krypton nuclides, for each of 3 to 33 days after removal from the reactor. For the 1959 accident, the ORIGEN2 nuclide list for each of the 1–8 days after the criticality event.

ACTIVITY—The inventory (Ci) of solid radionuclides contributing to (β-I) activity in a typical MTR fuel element, 3 to 33 days cooling, estimated by ORIGEN2 for the RaLa run 2 element.

EFFECTIVE ACTIVITY—The ACTIVITY multiplied by the factor, Y, described in Appendix D, i.e., the number of betas plus ejected electrons (detectable by the 1957–1959 β-detector system) per disintegration.

CONTRIBUTION—The percent of the effective (β-I) activity of a given nuclide in the fuel contributing to the (β-I) reported release.

The EFFECTIVE ACTIVITY may occasionally exceed the ACTIVITY value given by ORIGEN2. The reason is that more than one electron (exceeding the estimated detector cut-off energy of 25 keV) can be emitted by the nuclide. The tables also shows that electrons ejected from the valence shell of metastable nuclides generally exceed 25 keV and thus are counted along with the betas.

Generally, the Effective Activity very nearly equals the actual Activity for a given nuclide. One notable exception is Ru-106, which has no detectable betas. Also, Tc-99m emits significantly fewer detectable betas than indicated by its curies level. Two cases where the Effective Activity significantly exceeds the actual nuclide Activity are Eu-156 and Nd-147.

Table C.1 Activity (Ci) of solid radionuclides in a typical material testing reactor feed element, from 3–33 days cooling; and fractional contributions of each solid radionuclide to beta-minus iodine aerosol releases, from 3–33 days cooling

Table C.1 is presented on the following pages.

Table C.1 Day 3 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	4.78E+04	4.91E+04	11.016	**Ag-111**	1.26E+02	1.26E+02	0.028
Pr-143	4.39E+04	4.39E+04	9.858	**Cs-136**	9.47E+01	1.24E+02	0.028
Ba-140	4.39E+04	5.22E+04	11.712	**Sn-125**	8.46E+01	8.43E+01	0.019
Ce-141	3.06E+04	3.78E+04	8.485	**Pm-148m**	7.32E+01	8.43E+01	0.019
Mo-99	3.03E+04	3.09E+04	6.933	**Cs-134**	7.30E+01	5.39E+01	0.012
Tc-99m	2.92E+04	3.22E+03	0.722	**Pr-144m**	6.22E+01	4.29E+01	0.01
Te-132	2.38E+04	3.00E+04	6.726	**In-115m**	5.26E+01	2.89E+01	0.006
Zr-95	2.21E+04	2.21E+04	4.963	**Cd-115**	4.84E+01	4.89E+01	0.011
Y-91	2.17E+04	2.17E+04	4.862	**Te-127m**	4.54E+01	4.66E+01	0.01
Sr-89	1.89E+04	1.89E+04	4.245	**Th-231**	2.90E-04	6.18E-04	0
Nd-147	1.55E+04	2.52E+04	5.647	**Th-234**	3.42E-06	3.15E-06	0
Ce-143	1.44E+04	1.74E+04	3.902	**Pa-232**	4.45E-05	1.03E-04	0
Ru-103	1.42E+04	1.44E+04	3.222	**Pa-233**	4.81E-05	8.66E-05	0
Rh-103m	1.28E+04	1.15E+04	2.587	**Pa-234m**	3.42E-06	3.46E-06	0
Nb-95	9.17E+03	9.18E+03	2.06	**U-234**	5.58E-04	1.55E-04	0
Pm-149	6.65E+03	6.67E+03	1.495	**U-235**	2.68E-04	1.33E-04	0
Pr-144	5.18E+03	5.18E+03	1.163	**U-236**	7.33E-04	1.91E-04	0
Ce-144	5.18E+03	6.02E+03	1.351	**U-237**	7.65E+03	1.71E+04	3.837
Nb-97	3.44E+03	3.45E+03	0.773	**U-238**	4.35E-06	9.97E-07	0
Zr-97	3.42E+03	3.43E+03	0.768	**U-240**	1.32E-03	1.75E-03	0
Nb-97m	3.24E+03	6.71E+01	0.015	**Np-235**	1.44E-06	4.63E-08	0
Rh-105	1.89E+03	1.89E+03	0.425	**Np-236m**	2.84E-03	1.66E-03	0
Sm-153	1.65E+03	2.64E+03	0.593	**Np-237**	1.57E-04	1.79E-04	0
Pm-148	1.31E+03	1.31E+03	0.295	**Np-238**	3.24E+02	4.96E+02	0.111
Te-127	9.65E+02	9.66E+02	0.217	**Np-239**	8.46E+02	1.97E+03	0.441
Sb-127	9.62E+02	1.02E+03	0.228	**Np-240m**	1.33E-03	2.06E-03	0
Te-131m	8.49E+02	1.01E+03	0.226	**Pu-236**	8.73E-05	2.85E-05	0
Pm-151	7.73E+02	9.57E+02	0.215	**Pu-237**	5.50E-05	4.84E-06	0
Y-93	5.06E+02	5.07E+02	0.114	**Pu-238**	2.12E-01	3.69E-02	0
Te-129m	3.69E+02	3.74E+02	0.084	**Pu-239**	3.00E-03	2.35E-04	0
Pm-147	3.53E+02	3.53E+02	0.079	**Pu-240**	1.87E-03	3.09E-04	0
Sr-91	3.39E+02	3.39E+02	0.076	**Pu-241**	3.35E-01	2.17E-05	0
Eu-156	3.06E+02	4.18E+02	0.094	**Pu-242**	9.97E-07	1.37E-07	0
Rh-106	2.98E+02	2.99E+02	0.067	**Pu-243**	6.35E-05	7.11E-05	0
Ru-106	2.98E+02	0.00E+00	0	**Am-241**	1.73E-05	1.27E-05	0
Te-129	2.40E+02	2.80E+02	0.063	**Am-242**	3.22E-03	3.29E-03	0
Y-91m	2.15E+02	1.08E+01	0.002	**Am-243**	2.46E-06	7.67E-07	0
Te-131	1.91E+02	2.25E+02	0.051	**Am-244**	3.50E-05	9.83E-05	0
Cs-137	1.62E+02	1.62E+02	0.036	**Cm-242**	2.19E-03	3.44E-04	0
Sr-90	1.56E+02	1.56E+02	0.035	**Cm-244**	6.01E-05	4.04E-06	0
Y-90	1.55E+02	1.55E+02	0.035				
Ba-137m	1.53E+02	1.69E+01	0.004				
Nb-95m	1.48E+02	1.10E+02	0.025	**Total**	4.27E+05	4.46E+05	100

Table C.1 Day 4 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	4.60E+04	4.73E+04	11.718	**Cs-136**	8.98E+01	1.18E+02	0.029
Pr-143	4.23E+04	4.23E+04	10.478	**Sn-125**	7.87E+01	7.84E+01	0.019
Ba-140	4.16E+04	4.94E+04	12.243	**Cs-134**	7.29E+01	5.38E+01	0.013
Ce-141	3.00E+04	3.70E+04	9.17	**Pm-148m**	7.19E+01	8.29E+01	0.021
Mo-99	2.35E+04	2.40E+04	5.946	**Pr-144m**	6.21E+01	4.28E+01	0.011
Tc-99m	2.27E+04	2.50E+03	0.619	**Sr-91**	5.88E+01	5.89E+01	0.015
Zr-95	2.19E+04	2.19E+04	5.418	**Te-127m**	4.59E+01	4.71E+01	0.012
Y-91	2.14E+04	2.14E+04	5.302	**In-115m**	3.85E+01	2.11E+01	0.005
Te-132	1.92E+04	2.42E+04	6	**Th-231**	2.80E-04	5.96E-04	0
Sr-89	1.87E+04	1.87E+04	4.623	**Th-234**	3.45E-06	3.17E-06	0
Nd-147	1.46E+04	2.36E+04	5.854	**Pa-232**	2.62E-05	6.04E-05	0
Ru-103	1.39E+04	1.41E+04	3.492	**Pa-233**	5.09E-05	9.17E-05	0
Rh-103m	1.26E+04	1.13E+04	2.806	**Pa-234m**	3.45E-06	3.48E-06	0
Nb-95	9.42E+03	9.43E+03	2.335	**U-234**	5.58E-04	1.55E-04	0
Ce-143	8.70E+03	1.05E+04	2.603	**U-235**	2.68E-04	1.33E-04	0
Pr-144	5.17E+03	5.17E+03	1.281	**U-236**	7.33E-04	1.91E-04	0
Ce-144	5.17E+03	6.01E+03	1.487	**U-237**	6.90E+03	1.54E+04	3.821
Pm-149	4.86E+03	4.87E+03	1.206	**U-238**	4.35E-06	9.97E-07	0
Nb-97	1.29E+03	1.29E+03	0.319	**U-240**	4.04E-04	5.37E-04	0
Zr-97	1.28E+03	1.28E+03	0.317	**Np-235**	1.44E-06	4.62E-08	0
Nb-97m	1.21E+03	2.51E+01	0.006	**Np-236m**	1.36E-03	7.95E-04	0
Rh-105	1.18E+03	1.18E+03	0.293	**Np-237**	1.64E-04	1.87E-04	0
Sm-153	1.16E+03	1.85E+03	0.458	**Np-238**	2.33E+02	3.57E+02	0.089
Pm-148	1.15E+03	1.16E+03	0.286	**Np-239**	6.31E+02	1.47E+03	0.363
Te-127	8.14E+02	8.15E+02	0.202	**Np-240m**	4.08E-04	6.34E-04	0
Sb-127	8.04E+02	8.49E+02	0.21	**Pu-236**	8.79E-05	2.87E-05	0
Te-131m	4.88E+02	5.80E+02	0.144	**Pu-237**	5.42E-05	4.77E-06	0
Pm-151	4.31E+02	5.32E+02	0.132	**Pu-238**	2.18E-01	3.80E-02	0
Pm-147	3.64E+02	3.64E+02	0.09	**Pu-239**	3.06E-03	2.39E-04	0
Te-129m	3.61E+02	3.66E+02	0.091	**Pu-240**	1.87E-03	3.09E-04	0
Rh-106	2.98E+02	2.98E+02	0.074	**Pu-241**	3.35E-01	2.17E-05	0
Ru-106	2.98E+02	0.00E+00	0	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	2.93E+02	3.99E+02	0.099	**Pu-243**	2.21E-06	2.48E-06	0
Te-129	2.35E+02	2.74E+02	0.068	**Am-241**	1.88E-05	1.38E-05	0
Cs-137	1.62E+02	1.62E+02	0.04	**Am-242**	1.14E-03	1.16E-03	0
Sr-90	1.56E+02	1.56E+02	0.039	**Am-243**	2.46E-06	7.67E-07	0
Y-90	1.56E+02	1.56E+02	0.039	**Am-244**	6.74E-06	1.89E-05	0
Ba-137m	1.53E+02	1.69E+01	0.004	**Cm-242**	2.19E-03	3.43E-04	0
Nb-95m	1.49E+02	1.11E+02	0.027	**Cm-244**	6.01E-05	4.04E-06	0
Ag-111	1.15E+02	1.15E+02	0.028				
Te-131	1.10E+02	1.30E+02	0.032				
Y-93	9.74E+01	9.76E+01	0.024	**Total**	3.83E+05	4.04E+05	100

Table C.1 Day 5 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	4.41E+04	4.54E+04	12.177	**Cs-136**	8.52E+01	1.12E+02	0.03
Pr-143	4.05E+04	4.05E+04	10.883	**Sn-125**	7.32E+01	7.30E+01	0.02
Ba-140	3.94E+04	4.68E+04	12.574	**Cs-134**	7.29E+01	5.38E+01	0.014
Ce-141	2.94E+04	3.62E+04	9.728	**Pm-148m**	7.07E+01	8.16E+01	0.022
Zr-95	2.16E+04	2.17E+04	5.812	**Te-131**	6.31E+01	7.44E+01	0.02
Y-91	2.12E+04	2.12E+04	5.68	**Pr-144m**	6.19E+01	4.27E+01	0.011
Sr-89	1.84E+04	1.84E+04	4.942	**Te-127m**	4.63E+01	4.75E+01	0.013
Mo-99	1.83E+04	1.87E+04	5.009	**Th-231**	2.74E-04	5.84E-04	0
Tc-99m	1.76E+04	1.94E+03	0.522	**Th-234**	3.47E-06	3.20E-06	0
Te-132	1.55E+04	1.96E+04	5.259	**Pa-232**	1.54E-05	3.56E-05	0
Ru-103	1.37E+04	1.39E+04	3.721	**Pa-233**	5.39E-05	9.70E-05	0
Nd-147	1.37E+04	2.22E+04	5.962	**Pa-234m**	3.47E-06	3.51E-06	0
Rh-103m	1.23E+04	1.11E+04	2.988	**U-234**	5.58E-04	1.55E-04	0
Nb-95	9.66E+03	9.67E+03	2.596	**U-235**	2.68E-04	1.33E-04	0
Ce-143	5.26E+03	6.35E+03	1.704	**U-236**	7.33E-04	1.91E-04	0
Pr-144	5.16E+03	5.16E+03	1.385	**U-237**	6.23E+03	1.39E+04	3.739
Ce-144	5.16E+03	5.99E+03	1.608	**U-238**	4.35E-06	9.97E-07	0
Pm-149	3.55E+03	3.56E+03	0.956	**U-240**	1.24E-04	1.65E-04	0
Pm-148	1.01E+03	1.02E+03	0.273	**Np-235**	1.43E-06	4.61E-08	0
Sm-153	8.10E+02	1.30E+03	0.348	**Np-236m**	6.47E-04	3.79E-04	0
Rh-105	7.36E+02	7.39E+02	0.198	**Np-237**	1.70E-04	1.93E-04	0
Te-127	6.88E+02	6.89E+02	0.185	**Np-238**	1.68E+02	2.58E+02	0.069
Sb-127	6.71E+02	7.09E+02	0.19	**Np-239**	4.70E+02	1.09E+03	0.293
Nb-97	4.80E+02	4.81E+02	0.129	**Np-240m**	1.25E-04	1.95E-04	0
Zr-97	4.78E+02	4.78E+02	0.128	**Pu-236**	8.82E-05	2.87E-05	0
Nb-97m	4.52E+02	9.37E+00	0.003	**Pu-237**	5.33E-05	4.70E-06	0
Pm-147	3.74E+02	3.74E+02	0.1	**Pu-238**	2.22E-01	3.87E-02	0
Te-129m	3.54E+02	3.58E+02	0.096	**Pu-239**	3.10E-03	2.43E-04	0
Rh-106	2.97E+02	2.98E+02	0.08	**Pu-240**	1.87E-03	3.09E-04	0
Ru-106	2.97E+02	0.00E+00	0	**Pu-241**	3.35E-01	2.17E-05	0
Te-131m	2.80E+02	3.33E+02	0.089	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	2.80E+02	3.81E+02	0.102	**Am-241**	2.02E-05	1.48E-05	0
Pm-151	2.40E+02	2.96E+02	0.08	**Am-242**	4.03E-04	4.12E-04	0
Te-129	2.30E+02	2.68E+02	0.072	**Am-243**	2.46E-06	7.67E-07	0
Cs-137	1.62E+02	1.62E+02	0.043	**Am-244**	1.30E-06	3.65E-06	0
Sr-90	1.56E+02	1.56E+02	0.042	**Cm-242**	2.18E-03	3.42E-04	0
Y-90	1.56E+02	1.56E+02	0.042	**Cm-244**	6.01E-05	4.04E-06	0
Ba-137m	1.53E+02	1.69E+01	0.005				
Nb-95m	1.50E+02	1.11E+02	0.03				
Ag-111	1.04E+02	1.05E+02	0.028	**Total**	3.50E+05	3.73E+05	100

Table C.1 Day 6 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	4.21E+04	4.33E+04	12.462	**Ag-111**	9.50E+01	9.53E+01	0.027
Pr-143	3.87E+04	3.87E+04	11.142	**Cs-136**	8.08E+01	1.06E+02	0.031
Ba-140	3.73E+04	4.44E+04	12.764	**Cs-134**	7.28E+01	5.37E+01	0.015
Ce-141	2.87E+04	3.55E+04	10.207	**Pm-148m**	6.96E+01	8.02E+01	0.023
Zr-95	2.14E+04	2.14E+04	6.159	**Sn-125**	6.82E+01	6.79E+01	0.02
Y-91	2.09E+04	2.09E+04	6.015	**Pr-144m**	6.18E+01	4.26E+01	0.012
Sr-89	1.82E+04	1.82E+04	5.224	**Te-127m**	4.65E+01	4.77E+01	0.014
Mo-99	1.42E+04	1.45E+04	4.171	**Te-131**	3.62E+01	4.27E+01	0.012
Tc-99m	1.37E+04	1.51E+03	0.435	**Th-231**	2.72E-04	5.78E-04	0
Ru-103	1.35E+04	1.36E+04	3.918	**Th-234**	3.50E-06	3.22E-06	0
Nd-147	1.29E+04	2.09E+04	6.001	**Pa-232**	9.10E-06	2.10E-05	0
Te-132	1.26E+04	1.58E+04	4.554	**Pa-233**	5.69E-05	1.02E-04	0
Rh-103m	1.21E+04	1.09E+04	3.144	**Pa-234m**	3.50E-06	3.53E-06	0
Nb-95	9.89E+03	9.90E+03	2.849	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.15E+03	5.15E+03	1.48	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.15E+03	5.98E+03	1.719	**U-236**	7.33E-04	1.91E-04	0
Ce-143	3.18E+03	3.83E+03	1.103	**U-237**	5.62E+03	1.26E+04	3.616
Pm-149	2.60E+03	2.60E+03	0.749	**U-238**	4.35E-06	9.97E-07	0
Pm-148	8.91E+02	8.93E+02	0.257	**U-240**	3.82E-05	5.07E-05	0
Te-127	5.82E+02	5.83E+02	0.168	**Np-235**	1.43E-06	4.60E-08	0
Sm-153	5.67E+02	9.07E+02	0.261	**Np-236m**	3.09E-04	1.81E-04	0
Sb-127	5.61E+02	5.92E+02	0.17	**Np-237**	1.75E-04	1.99E-04	0
Rh-105	4.60E+02	4.62E+02	0.133	**Np-238**	1.21E+02	1.86E+02	0.053
Pm-147	3.83E+02	3.83E+02	0.11	**Np-239**	3.50E+02	8.13E+02	0.234
Te-129m	3.47E+02	3.51E+02	0.101	**Np-240m**	3.85E-05	5.98E-05	0
Rh-106	2.97E+02	2.97E+02	0.085	**Pu-236**	8.83E-05	2.88E-05	0
Ru-106	2.97E+02	0.00E+00	0	**Pu-237**	5.25E-05	4.63E-06	0
Eu-156	2.67E+02	3.64E+02	0.105	**Pu-238**	2.25E-01	3.93E-02	0
Te-129	2.26E+02	2.63E+02	0.076	**Pu-239**	3.13E-03	2.45E-04	0
Nb-97	1.79E+02	1.80E+02	0.052	**Pu-240**	1.87E-03	3.09E-04	0
Zr-97	1.79E+02	1.79E+02	0.051	**Pu-241**	3.35E-01	2.17E-05	0
Nb-97m	1.69E+02	3.50E+00	0.001	**Pu-242**	9.97E-07	1.37E-07	0
Cs-137	1.62E+02	1.62E+02	0.046	**Am-241**	2.17E-05	1.59E-05	0
Te-131m	1.61E+02	1.91E+02	0.055	**Am-242**	1.43E-04	1.46E-04	0
Sr-90	1.56E+02	1.56E+02	0.045	**Am-243**	2.46E-06	7.67E-07	0
Y-90	1.56E+02	1.56E+02	0.045	**Cm-242**	2.17E-03	3.41E-04	0
Ba-137m	1.53E+02	1.69E+01	0.005	**Cm-244**	6.01E-05	4.04E-06	0
Nb-95m	1.50E+02	1.11E+02	0.032				
Pm-151	1.33E+02	1.65E+02	0.047	**Total**	3.25E+05	3.48E+05	100

Table C.1 Day 7 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	4.01E+04	4.13E+04	12.624	**Cs-134**	7.27E+01	5.37E+01	0.016
Pr-143	3.69E+04	3.69E+04	11.293	**Pm-148m**	6.84E+01	7.89E+01	0.024
Ba-140	3.53E+04	4.20E+04	12.853	**Nb-97**	6.70E+01	6.72E+01	0.021
Ce-141	2.81E+04	3.47E+04	10.623	**Zr-97**	6.67E+01	6.68E+01	0.02
Zr-95	2.12E+04	2.12E+04	6.479	**Sn-125**	6.34E+01	6.32E+01	0.019
Y-91	2.07E+04	2.07E+04	6.323	**Nb-97m**	6.32E+01	1.31E+00	0
Sr-89	1.79E+04	1.79E+04	5.478	**Pr-144m**	6.16E+01	4.25E+01	0.013
Ru-103	1.32E+04	1.34E+04	4.093	**Te-127m**	4.67E+01	4.79E+01	0.015
Nd-147	1.21E+04	1.96E+04	5.992	**Th-231**	2.70E-04	5.75E-04	0
Rh-103m	1.19E+04	1.07E+04	3.285	**Th-234**	3.52E-06	3.24E-06	0
Mo-99	1.11E+04	1.13E+04	3.447	**Pa-232**	5.36E-06	1.24E-05	0
Tc-99m	1.06E+04	1.17E+03	0.359	**Pa-233**	5.99E-05	1.08E-04	0
Te-132	1.02E+04	1.28E+04	3.915	**Pa-234m**	3.52E-06	3.56E-06	0
Nb-95	1.01E+04	1.01E+04	3.099	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.13E+03	5.13E+03	1.57	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.13E+03	5.96E+03	1.824	**U-236**	7.33E-04	1.91E-04	0
Ce-143	1.92E+03	2.32E+03	0.708	**U-237**	5.07E+03	1.13E+04	3.469
Pm-149	1.90E+03	1.90E+03	0.582	**U-238**	4.35E-06	9.97E-07	0
Pm-148	7.83E+02	7.86E+02	0.24	**U-240**	1.17E-05	1.56E-05	0
Te-127	4.94E+02	4.95E+02	0.151	**Np-235**	1.43E-06	4.59E-08	0
Sb-127	4.68E+02	4.95E+02	0.151	**Np-236m**	1.48E-04	8.65E-05	0
Sm-153	3.97E+02	6.35E+02	0.194	**Np-237**	1.80E-04	2.05E-04	0
Pm-147	3.92E+02	3.92E+02	0.12	**Np-238**	8.73E+01	1.34E+02	0.041
Te-129m	3.40E+02	3.44E+02	0.105	**Np-239**	2.61E+02	6.06E+02	0.185
Rh-106	2.96E+02	2.96E+02	0.091	**Np-240m**	1.18E-05	1.84E-05	0
Ru-106	2.96E+02	0.00E+00	0	**Pu-236**	8.83E-05	2.88E-05	0
Rh-105	2.87E+02	2.88E+02	0.088	**Pu-237**	5.17E-05	4.56E-06	0
Eu-156	2.55E+02	3.48E+02	0.106	**Pu-238**	2.28E-01	3.96E-02	0
Te-129	2.21E+02	2.57E+02	0.079	**Pu-239**	3.16E-03	2.47E-04	0
Cs-137	1.62E+02	1.62E+02	0.049	**Pu-240**	1.87E-03	3.09E-04	0
Sr-90	1.56E+02	1.56E+02	0.048	**Pu-241**	3.35E-01	2.17E-05	0
Y-90	1.56E+02	1.56E+02	0.048	**Pu-242**	9.97E-07	1.37E-07	0
Ba-137m	1.53E+02	1.69E+01	0.005	**Am-241**	2.32E-05	1.70E-05	0
Nb-95m	1.50E+02	1.11E+02	0.034	**Am-242**	5.10E-05	5.21E-05	0
Te-131m	9.24E+01	1.10E+02	0.034	**Am-243**	2.46E-06	7.67E-07	0
Ag-111	8.66E+01	8.68E+01	0.027	**Cm-242**	2.16E-03	3.40E-04	0
Cs-136	7.66E+01	1.01E+02	0.031	**Cm-244**	6.01E-05	4.04E-06	0
Pm-151	7.42E+01	9.18E+01	0.028	**Total**	3.05E+05	3.27E+05	100

Table C.1 Day 8 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	3.82E+04	3.93E+04	12.69	**Pr-144m**	6.15E+01	4.24E+01	0.014
Pr-143	3.52E+04	3.52E+04	11.368	**Sn-125**	5.90E+01	5.88E+01	0.019
Ba-140	3.35E+04	3.98E+04	12.871	**Te-131m**	5.31E+01	6.31E+01	0.02
Ce-141	2.75E+04	3.40E+04	10.993	**Te-127m**	4.68E+01	4.80E+01	0.016
Zr-95	2.09E+04	2.10E+04	6.774	**Pm-151**	4.13E+01	5.11E+01	0.017
Y-91	2.04E+04	2.04E+04	6.602	**Th-231**	2.69E-04	5.73E-04	0
Sr-89	1.77E+04	1.77E+04	5.713	**Th-234**	3.55E-06	3.26E-06	0
Ru-103	1.30E+04	1.31E+04	4.248	**Pa-232**	3.16E-06	7.28E-06	0
Rh-103m	1.17E+04	1.06E+04	3.411	**Pa-233**	6.30E-05	1.13E-04	0
Nd-147	1.13E+04	1.84E+04	5.949	**Pa-234m**	3.55E-06	3.58E-06	0
Nb-95	1.03E+04	1.03E+04	3.343	**U-234**	5.58E-04	1.55E-04	0
Mo-99	8.59E+03	8.76E+03	2.833	**U-235**	2.68E-04	1.33E-04	0
Tc-99m	8.27E+03	9.13E+02	0.295	**U-236**	7.33E-04	1.91E-04	0
Te-132	8.21E+03	1.04E+04	3.346	**U-237**	4.58E+03	1.02E+04	3.308
Pr-144	5.12E+03	5.12E+03	1.656	**U-238**	4.35E-06	9.97E-07	0
Ce-144	5.12E+03	5.95E+03	1.923	**U-240**	3.61E-06	4.79E-06	0
Pm-149	1.39E+03	1.39E+03	0.45	**Np-235**	1.43E-06	4.59E-08	0
Ce-143	1.16E+03	1.40E+03	0.452	**Np-236m**	7.04E-05	4.13E-05	0
Pm-148	6.89E+02	6.91E+02	0.223	**Np-237**	1.84E-04	2.10E-04	0
Te-127	4.20E+02	4.21E+02	0.136	**Np-238**	6.29E+01	9.65E+01	0.031
Pm-147	4.00E+02	4.00E+02	0.129	**Np-239**	1.94E+02	4.51E+02	0.146
Sb-127	3.91E+02	4.13E+02	0.134	**Np-240m**	3.64E-06	5.65E-06	0
Te-129m	3.33E+02	3.37E+02	0.109	**Pu-236**	8.83E-05	2.88E-05	0
Rh-106	2.95E+02	2.96E+02	0.096	**Pu-237**	5.10E-05	4.49E-06	0
Ru-106	2.95E+02	0.00E+00	0	**Pu-238**	2.29E-01	3.99E-02	0
Sm-153	2.78E+02	4.45E+02	0.144	**Pu-239**	3.18E-03	2.48E-04	0
Eu-156	2.44E+02	3.32E+02	0.107	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	2.17E+02	2.52E+02	0.081	**Pu-241**	3.35E-01	2.17E-05	0
Rh-105	1.79E+02	1.80E+02	0.058	**Pu-242**	9.97E-07	1.37E-07	0
Cs-137	1.62E+02	1.62E+02	0.052	**Am-241**	2.47E-05	1.81E-05	0
S-090	1.56E+02	1.56E+02	0.051	**Am-242m**	5.39E-07	5.39E-07	0
Y-90	1.56E+02	1.56E+02	0.05	**Am-242**	1.84E-05	1.88E-05	0
Ba-137m	1.53E+02	1.69E+01	0.005	**Am-243**	2.46E-06	7.67E-07	0
Nb-95m	1.49E+02	1.11E+02	0.036	**Cm-242**	2.15E-03	3.38E-04	0
Ag-111	7.89E+01	7.91E+01	0.026	**Cm-244**	6.01E-05	4.04E-06	0
Cs-134	7.27E+01	5.36E+01	0.017				
Cs-136	7.27E+01	9.55E+01	0.031	**Total**	2.87E+05	3.09E+05	100
Pm-148m	6.73E+01	7.76E+01	0.025				

Table C.1 Day 9 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	3.63E+04	3.73E+04	12.68	**Pm-148m**	6.61E+01	7.63E+01	0.026
Pr-143	3.35E+04	3.35E+04	11.378	**Pr-144m**	6.13E+01	4.23E+01	0.014
Ba-140	3.17E+04	3.77E+04	12.827	**Sn-125**	5.49E+01	5.48E+01	0.019
Ce-141	2.70E+04	3.33E+04	11.32	**Te-127m**	4.68E+01	4.80E+01	0.016
Zr-95	2.07E+04	2.07E+04	7.051	**Te-131m**	3.05E+01	3.62E+01	0.012
Y-91	2.02E+04	2.02E+04	6.864	**Th-231**	2.69E-04	5.72E-04	0
Sr-89	1.74E+04	1.74E+04	5.929	**Th-234**	3.57E-06	3.28E-06	0
Ru-103	1.28E+04	1.29E+04	4.391	**Pa-232**	1.86E-06	4.29E-06	0
Rh-103m	1.15E+04	1.04E+04	3.527	**Pa-233**	6.61E-05	1.19E-04	0
Nd-147	1.07E+04	1.73E+04	5.878	**Pa-234m**	3.57E-06	3.61E-06	0
Nb-95	1.05E+04	1.05E+04	3.585	**U-234**	5.58E-04	1.55E-04	0
Mo-99	6.67E+03	6.81E+03	2.316	**U-235**	2.68E-04	1.33E-04	0
Te-132	6.64E+03	8.36E+03	2.845	**U-236**	7.33E-04	1.91E-04	0
Tc-99m	6.43E+03	7.09E+02	0.241	**U-237**	4.13E+03	9.24E+03	3.141
Pr-144	5.11E+03	5.11E+03	1.738	**U-238**	4.35E-06	9.97E-07	0
Ce-144	5.11E+03	5.93E+03	2.018	**U-240**	1.11E-06	1.47E-06	0
Pm-149	1.01E+03	1.02E+03	0.346	**Np-235**	1.42E-06	4.58E-08	0
Ce-143	7.00E+02	8.45E+02	0.287	**Np-236m**	3.36E-05	1.97E-05	0
Pm-148	6.06E+02	6.08E+02	0.207	**Np-237**	1.88E-04	2.14E-04	0
Pm-147	4.08E+02	4.08E+02	0.139	**Np-238**	4.54E+01	6.95E+01	0.024
Te-127	3.59E+02	3.59E+02	0.122	**Np-239**	1.45E+02	3.36E+02	0.114
Sb-127	3.27E+02	3.45E+02	0.117	**Np-240m**	1.12E-06	1.74E-06	0
Te-129m	3.26E+02	3.30E+02	0.112	**Pu-236**	8.82E-05	2.87E-05	0
Rh-106	2.95E+02	2.95E+02	0.1	**Pu-237**	5.02E-05	4.42E-06	0
Ru-106	2.95E+02	0.00E+00	0	**Pu-238**	2.30E-01	4.01E-02	0
Eu-156	2.33E+02	3.18E+02	0.108	**Pu-239**	3.19E-03	2.49E-04	0
Te-129	2.12E+02	2.47E+02	0.084	**Pu-240**	1.87E-03	3.09E-04	0
Sm-153	1.95E+02	3.12E+02	0.106	**Pu-241**	3.35E-01	2.17E-05	0
Cs-137	1.62E+02	1.62E+02	0.055	**Pu-242**	9.97E-07	1.37E-07	0
Sr-90	1.56E+02	1.56E+02	0.053	**Am-241**	2.61E-05	1.92E-05	0
Y-90	1.56E+02	1.56E+02	0.053	**Am-242m**	5.39E-07	5.39E-07	0
Ba-137m	1.53E+02	1.69E+01	0.006	**Am-242**	6.86E-06	7.01E-06	0
Nb-95m	1.49E+02	1.10E+02	0.037	**Am-243**	2.46E-06	7.67E-07	0
Rh-105	1.12E+02	1.13E+02	0.038	**Cm-242**	2.14E-03	3.37E-04	0
Cs-134	7.26E+01	5.36E+01	0.018	**Cm-244**	6.01E-05	4.04E-06	0
Ag-111	7.19E+01	7.21E+01	0.025				
Cs-136	6.89E+01	9.06E+01	0.031	**Total**	2.73E+05	2.94E+05	100

Table C.1 Day 10 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	3.44E+04	3.54E+04	12.613	**Cs-136**	6.54E+01	8.59E+01	0.031
Pr-143	3.18E+04	3.18E+04	11.34	**Pm-148m**	6.50E+01	7.50E+01	0.027
Ba-140	3.00E+04	3.57E+04	12.734	**Pr-144m**	6.12E+01	4.22E+01	0.015
Ce-141	2.64E+04	3.26E+04	11.615	**Sn-125**	5.11E+01	5.10E+01	0.018
Zr-95	2.05E+04	2.05E+04	7.308	**Te-127m**	4.67E+01	4.79E+01	0.017
Y-91	2.00E+04	2.00E+04	7.112	**Th-231**	2.69E-04	5.72E-04	0
Sr-89	1.72E+04	1.72E+04	6.128	**Th-234**	3.59E-06	3.31E-06	0
Ru-103	1.25E+04	1.27E+04	4.524	**Pa-232**	1.10E-06	2.53E-06	0
Rh-103m	1.13E+04	1.02E+04	3.633	**Pa-233**	6.93E-05	1.25E-04	0
Nb-95	1.07E+04	1.07E+04	3.829	**Pa-234m**	3.59E-06	3.63E-06	0
Nd-147	1.00E+04	1.62E+04	5.786	**U-234**	5.58E-04	1.55E-04	0
Te-132	5.37E+03	6.76E+03	2.41	**U-235**	2.68E-04	1.33E-04	0
Mo-99	5.19E+03	5.29E+03	1.887	**U-236**	7.33E-04	1.91E-04	0
Pr-144	5.10E+03	5.10E+03	1.817	**U-237**	3.73E+03	8.33E+03	2.971
Ce-144	5.10E+03	5.92E+03	2.11	**U-238**	4.35E-06	9.97E-07	0
Tc-99m	5.00E+03	5.51E+02	0.197	**Np-235**	1.42E-06	4.57E-08	0
Pm-149	7.41E+02	7.43E+02	0.265	**Np-236m**	1.61E-05	9.41E-06	0
Pm-148	5.33E+02	5.34E+02	0.191	**Np-237**	1.91E-04	2.18E-04	0
Ce-143	4.23E+02	5.10E+02	0.182	**Np-238**	3.27E+01	5.01E+01	0.018
Pm-147	4.15E+02	4.15E+02	0.148	**Np-239**	1.08E+02	2.51E+02	0.089
Te-129m	3.19E+02	3.23E+02	0.115	**Pu-236**	8.82E-05	2.87E-05	0
Te-127	3.07E+02	3.07E+02	0.11	**Pu-237**	4.94E-05	4.35E-06	0
Rh-106	2.94E+02	2.95E+02	0.105	**Pu-238**	2.31E-01	4.03E-02	0
Ru-106	2.94E+02	0.00E+00	0	**Pu-239**	3.20E-03	2.50E-04	0
Sb-127	2.73E+02	2.88E+02	0.103	**Pu-240**	1.87E-03	3.09E-04	0
Eu-156	2.23E+02	3.03E+02	0.108	**Pu-241**	3.35E-01	2.17E-05	0
Te-129	2.08E+02	2.42E+02	0.086	**Pu-242**	9.97E-07	1.37E-07	0
Cs-137	1.62E+02	1.62E+02	0.058	**Am-241**	2.76E-05	2.02E-05	0
Sr-90	1.56E+02	1.56E+02	0.056	**Am-242m**	5.39E-07	5.39E-07	0
Y-90	1.56E+02	1.56E+02	0.056	**Am-242**	2.78E-06	2.84E-06	0
Ba-137m	1.53E+02	1.69E+01	0.006	**Am-243**	2.46E-06	7.67E-07	0
Nb-95m	1.48E+02	1.10E+02	0.039	**Cm-242**	2.13E-03	3.35E-04	0
Sm-153	1.36E+02	2.18E+02	0.078	**Cm-244**	6.01E-05	4.04E-06	0
Cs-134	7.25E+01	5.35E+01	0.019				
Rh-105	7.00E+01	7.03E+01	0.025				
Ag-111	6.55E+01	6.57E+01	0.023	**Total**	2.60E+05	2.81E+05	100

Table C.1 Day 11 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	3.26E+04	3.36E+04	12.501	**Pr-144m**	6.10E+01	4.21E+01	0.016
Pr-143	3.03E+04	3.03E+04	11.268	**Ag-111**	5.97E+01	5.98E+01	0.022
Ba-140	2.85E+04	3.38E+04	12.601	**Sn-125**	4.76E+01	4.74E+01	0.018
Ce-141	2.58E+04	3.19E+04	11.879	**Te-127m**	4.67E+01	4.79E+01	0.018
Zr-95	2.03E+04	2.03E+04	7.554	**Rh-105**	4.37E+01	4.39E+01	0.016
Y-91	1.97E+04	1.97E+04	7.342	**Th-231**	2.69E-04	5.72E-04	0
Sr-89	1.70E+04	1.70E+04	6.317	**Th-234**	3.61E-06	3.32E-06	0
Ru-103	1.23E+04	1.25E+04	4.645	**Pa-232**	6.46E-07	1.49E-06	0
Rh-103m	1.11E+04	1.00E+04	3.729	**Pa-233**	7.24E-05	1.30E-04	0
Nb-95	1.09E+04	1.09E+04	4.071	**Pa-234m**	3.61E-06	3.65E-06	0
Nd-147	9.40E+03	1.53E+04	5.68	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.08E+03	5.08E+03	1.894	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.08E+03	5.90E+03	2.199	**U-236**	7.33E-04	1.91E-04	0
Te-132	4.34E+03	5.47E+03	2.036	**U-237**	3.36E+03	7.52E+03	2.801
Mo-99	4.03E+03	4.11E+03	1.532	**U-238**	4.35E-06	9.97E-07	0
Tc-99m	3.88E+03	4.28E+02	0.16	**Np-235**	1.42E-06	4.56E-08	0
Pm-149	5.42E+02	5.43E+02	0.202	**Np-236m**	7.66E-06	4.49E-06	0
Pm-148	4.69E+02	4.70E+02	0.175	**Np-237**	1.94E-04	2.21E-04	0
Pm-147	4.22E+02	4.22E+02	0.157	**Np-238**	2.36E+01	3.61E+01	0.013
Te-129m	3.13E+02	3.17E+02	0.118	**Np-239**	8.04E+01	1.87E+02	0.07
Rh-106	2.94E+02	2.94E+02	0.11	**Pu-236**	8.81E-05	2.87E-05	0
Ru-106	2.94E+02	0.00E+00	0	**Pu-237**	4.87E-05	4.29E-06	0
Te-127	2.64E+02	2.64E+02	0.098	**Pu-238**	2.32E-01	4.04E-02	0
Ce-143	2.55E+02	3.08E+02	0.115	**Pu-239**	3.21E-03	2.51E-04	0
Sb-127	2.28E+02	2.41E+02	0.09	**Pu-240**	1.87E-03	3.09E-04	0
Eu-156	2.13E+02	2.90E+02	0.108	**Pu-241**	3.35E-01	2.17E-05	0
Te-129	2.04E+02	2.37E+02	0.088	**Pu-242**	9.97E-07	1.37E-07	0
Cs-137	1.62E+02	1.62E+02	0.06	**Am-241**	2.91E-05	2.13E-05	0
Sr-90	1.56E+02	1.56E+02	0.058	**Am-242m**	5.39E-07	5.39E-07	0
Y-90	1.56E+02	1.56E+02	0.058	**Am-242**	1.33E-06	1.36E-06	0
Ba-137m	1.53E+02	1.69E+01	0.006	**Am-243**	2.46E-06	7.67E-07	0
Nb-95m	1.47E+02	1.09E+02	0.041	**Cm-242**	2.13E-03	3.34E-04	0
Sm-153	9.55E+01	1.53E+02	0.057	**Cm-244**	6.01E-05	4.04E-06	0
Cs-134	7.25E+01	5.35E+01	0.02				
Pm-148m	6.40E+01	7.37E+01	0.027				
Cs-136	6.20E+01	8.15E+01	0.03	**Total**	2.49E+05	2.68E+05	100

Table C.1 Day 12 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	3.09E+04	3.18E+04	12.354	**Cs-136**	5.88E+01	7.73E+01	0.03
Pr-143	2.88E+04	2.88E+04	11.162	**Ag-111**	5.44E+01	5.45E+01	0.021
Ba-140	2.70E+04	3.21E+04	12.443	**Te-127m**	4.66E+01	4.78E+01	0.019
Ce-141	2.53E+04	3.12E+04	12.121	**Sn-125**	4.43E+01	4.41E+01	0.017
Zr-95	2.00E+04	2.01E+04	7.792	**Rh-105**	2.73E+01	2.74E+01	0.011
Y-91	1.95E+04	1.95E+04	7.563	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.67E+04	1.67E+04	6.491	**Th-234**	3.63E-06	3.34E-06	0
Ru-103	1.21E+04	1.23E+04	4.756	**Pa-232**	3.81E-07	8.78E-07	0
Nb-95	1.11E+04	1.11E+04	4.313	**Pa-233**	7.55E-05	1.36E-04	0
Rh-103m	1.09E+04	9.83E+03	3.818	**Pa-234m**	3.63E-06	3.67E-06	0
Nd-147	8.83E+03	1.43E+04	5.56	**U-232**	3.30E-07	1.10E-07	0
Pr-144	5.07E+03	5.07E+03	1.969	**U-234**	5.58E-04	1.55E-04	0
Ce-144	5.07E+03	5.89E+03	2.287	**U-235**	2.68E-04	1.33E-04	0
Te-132	3.51E+03	4.42E+03	1.715	**U-236**	7.33E-04	1.91E-04	0
Mo-99	3.13E+03	3.20E+03	1.241	**U-237**	3.04E+03	6.79E+03	2.635
Tc-99m	3.02E+03	3.33E+02	0.129	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.28E+02	4.28E+02	0.166	**Np-235**	1.42E-06	4.55E-08	0
Pm-148	4.12E+02	4.14E+02	0.161	**Np-236m**	3.66E-06	2.15E-06	0
Pm-149	3.96E+02	3.97E+02	0.154	**Np-237**	1.97E-04	2.25E-04	0
Te-129m	3.06E+02	3.10E+02	0.12	**Np-238**	1.70E+01	2.60E+01	0.01
Rh-106	2.93E+02	2.94E+02	0.114	**Np-239**	5.99E+01	1.39E+02	0.054
Ru-106	2.93E+02	0.00E+00	0	**Pu-236**	8.80E-05	2.87E-05	0
Te-127	2.28E+02	2.28E+02	0.089	**Pu-237**	4.80E-05	4.22E-06	0
Eu-156	2.03E+02	2.77E+02	0.108	**Pu-238**	2.32E-01	4.05E-02	0
Te-129	1.99E+02	2.32E+02	0.09	**Pu-239**	3.21E-03	2.51E-04	0
Sb-127	1.90E+02	2.01E+02	0.078	**Pu-240**	1.87E-03	3.09E-04	0
Cs-137	1.62E+02	1.62E+02	0.063	**Pu-241**	3.35E-01	2.17E-05	0
Sr-90	1.56E+02	1.56E+02	0.061	**Pu-242**	9.97E-07	1.37E-07	0
Y-90	1.56E+02	1.56E+02	0.061	**Am-241**	3.05E-05	2.24E-05	0
Ce-143	1.54E+02	1.86E+02	0.072	**Am-242m**	5.39E-07	5.39E-07	0
Ba-137m	1.53E+02	1.69E+01	0.007	**Am-242**	8.17E-07	8.35E-07	0
Nb-95m	1.46E+02	1.08E+02	0.042	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.24E+01	5.34E+01	0.021	**Cm-242**	2.12E-03	3.32E-04	0
Sm-153	6.69E+01	1.07E+02	0.042	**Cm-244**	6.01E-05	4.04E-06	0
Pm-148m	6.29E+01	7.25E+01	0.028				
Pr-144m	6.09E+01	4.20E+01	0.016	**Total**	2.38E+05	2.58E+05	100

Table C.1 Day 13 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.93E+04	3.02E+04	12.18	**Cs-136**	5.58E+01	7.33E+01	0.03
Pr-143	2.73E+04	2.73E+04	11.033	**Ag-111**	4.96E+01	4.97E+01	0.02
Ba-140	2.55E+04	3.04E+04	12.26	**Sm-153**	4.69E+01	7.49E+01	0.03
Ce-141	2.48E+04	3.06E+04	12.341	**Te-127m**	4.64E+01	4.76E+01	0.019
Zr-95	1.98E+04	1.99E+04	8.016	**Sn-125**	4.12E+01	4.11E+01	0.017
Y-91	1.93E+04	1.93E+04	7.774	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.65E+04	1.65E+04	6.663	**Th-234**	3.65E-06	3.36E-06	0
Ru-103	1.19E+04	1.20E+04	4.858	**Pa-233**	7.86E-05	1.42E-04	0
Nb-95	1.13E+04	1.13E+04	4.555	**Pa-234m**	3.65E-06	3.69E-06	0
Rh-103m	1.07E+04	9.66E+03	3.902	**U-232**	3.32E-07	1.11E-07	0
Nd-147	8.29E+03	1.35E+04	5.432	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.06E+03	5.06E+03	2.043	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.06E+03	5.88E+03	2.373	**U-236**	7.33E-04	1.91E-04	0
Te-132	2.83E+03	3.57E+03	1.442	**U-237**	2.74E+03	6.12E+03	2.473
Mo-99	2.43E+03	2.49E+03	1.004	**U-238**	4.35E-06	9.97E-07	0
Tc-99m	2.35E+03	2.59E+02	0.105	**Np-235**	1.41E-06	4.55E-08	0
Pm-147	4.34E+02	4.34E+02	0.175	**Np-236m**	1.75E-06	1.02E-06	0
Pm-148	3.63E+02	3.64E+02	0.147	**Np-237**	2.00E-04	2.28E-04	0
Te-129m	3.00E+02	3.04E+02	0.123	**Np-238**	1.22E+01	1.88E+01	0.008
Rh-106	2.93E+02	2.93E+02	0.118	**Np-239**	4.46E+01	1.04E+02	0.042
Ru-106	2.93E+02	0.00E+00	0	**Pu-236**	8.80E-05	2.87E-05	0
Pm-149	2.89E+02	2.90E+02	0.117	**Pu-237**	4.72E-05	4.16E-06	0
Te-127	1.98E+02	1.98E+02	0.08	**Pu-238**	2.33E-01	4.05E-02	0
Te-129	1.95E+02	2.27E+02	0.092	**Pu-239**	3.22E-03	2.52E-04	0
Eu-156	1.94E+02	2.65E+02	0.107	**Pu-240**	1.87E-03	3.09E-04	0
Cs-137	1.62E+02	1.62E+02	0.065	**Pu-241**	3.35E-01	2.17E-05	0
Sb-127	1.59E+02	1.68E+02	0.068	**Pu-242**	9.97E-07	1.37E-07	0
Sr-90	1.56E+02	1.56E+02	0.063	**Am-241**	3.20E-05	2.35E-05	0
Y-90	1.56E+02	1.56E+02	0.063	**Am-242m**	5.39E-07	5.39E-07	0
Ba-137m	1.53E+02	1.69E+01	0.007	**Am-242**	6.36E-07	6.50E-07	0
Nb-95m	1.45E+02	1.07E+02	0.043	**Am-243**	2.46E-06	7.67E-07	0
Ce-143	9.32E+01	1.13E+02	0.045	**Cm-242**	2.11E-03	3.31E-04	0
Cs-134	7.23E+01	5.34E+01	0.022	**Cm-244**	6.01E-05	4.04E-06	0
Pm-148m	6.18E+01	7.13E+01	0.029				
Pr-144m	6.07E+01	4.19E+01	0.017	**Total**	2.29E+05	2.48E+05	100

Table C.1 Day 14 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.78E+04	2.86E+04	11.982	**Cs-136**	5.29E+01	6.95E+01	0.029
Pr-143	2.60E+04	2.60E+04	10.887	**Te-127m**	4.62E+01	4.74E+01	0.02
Ce-141	2.42E+04	2.99E+04	12.543	**Ag-111**	4.51E+01	4.53E+01	0.019
Ba-140	2.42E+04	2.88E+04	12.057	**Sn-125**	3.84E+01	3.82E+01	0.016
Zr-95	1.96E+04	1.96E+04	8.234	**Sm-153**	3.28E+01	5.25E+01	0.022
Y-91	1.90E+04	1.90E+04	7.974	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.63E+04	1.63E+04	6.821	**Th-234**	3.67E-06	3.38E-06	0
Ru-103	1.17E+04	1.18E+04	4.955	**Pa-233**	8.17E-05	1.47E-04	0
Nb-95	1.14E+04	1.15E+04	4.8	**Pa-234m**	3.67E-06	3.71E-06	0
Rh-103m	1.05E+04	9.49E+03	3.98	**U-232**	3.34E-07	1.11E-07	0
Nd-147	7.79E+03	1.26E+04	5.295	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.05E+03	5.05E+03	2.116	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.05E+03	5.86E+03	2.457	**U-236**	7.33E-04	1.91E-04	0
Te-132	2.29E+03	2.89E+03	1.21	**U-237**	2.47E+03	5.53E+03	2.317
Mo-99	1.89E+03	1.93E+03	0.81	**U-238**	4.35E-06	9.97E-07	0
Tc-99m	1.82E+03	2.01E+02	0.084	**Np-235**	1.41E-06	4.54E-08	0
Pm-147	4.39E+02	4.39E+02	0.184	**Np-236m**	8.34E-07	4.89E-07	0
Pm-148	3.19E+02	3.20E+02	0.134	**Np-237**	2.02E-04	2.30E-04	0
Te-129m	2.94E+02	2.98E+02	0.125	**Np-238**	8.83E+00	1.35E+01	0.006
Rh-106	2.92E+02	2.93E+02	0.123	**Np-239**	3.32E+01	7.72E+01	0.032
Ru-106	2.92E+02	0.00E+00	0	**Pu-236**	8.79E-05	2.87E-05	0
Pm-149	2.12E+02	2.12E+02	0.089	**Pu-237**	4.65E-05	4.10E-06	0
Te-129	1.91E+02	2.23E+02	0.093	**Pu-238**	2.33E-01	4.05E-02	0
Eu-156	1.85E+02	2.53E+02	0.106	**Pu-239**	3.22E-03	2.52E-04	0
Te-127	1.72E+02	1.73E+02	0.072	**Pu-240**	1.87E-03	3.09E-04	0
Cs-137	1.62E+02	1.62E+02	0.068	**Pu-241**	3.35E-01	2.17E-05	0
Sr-90	1.56E+02	1.56E+02	0.066	**Pu-242**	9.97E-07	1.37E-07	0
Y-90	1.56E+02	1.56E+02	0.066	**Am-241**	3.35E-05	2.45E-05	0
Ba-137m	1.53E+02	1.69E+01	0.007	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.44E+02	1.06E+02	0.045	**Am-242**	5.72E-07	5.84E-07	0
Sb-127	1.33E+02	1.40E+02	0.059	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.23E+01	5.33E+01	0.022	**Cm-242**	2.10E-03	3.30E-04	0
Pm-148m	6.08E+01	7.01E+01	0.029	**Cm-244**	6.01E-05	4.04E-06	0
Pr-144m	6.06E+01	4.18E+01	0.018				
Ce-143	5.63E+01	6.80E+01	0.028	**Total**	2.21E+05	2.39E+05	100

Table C.1 Day 15 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.63E+04	2.71E+04	11.768	**Te-127m**	4.61E+01	4.72E+01	0.021
Pr-143	2.47E+04	2.47E+04	10.72	**Ag-111**	4.11E+01	4.12E+01	0.018
Ce-141	2.37E+04	2.93E+04	12.728	**Sn-125**	3.57E+01	3.56E+01	0.015
Ba-140	2.29E+04	2.72E+04	11.837	**Ce-143**	3.40E+01	4.10E+01	0.018
Zr-95	1.94E+04	1.94E+04	8.439	**Sm-153**	2.30E+01	3.67E+01	0.016
Y-91	1.88E+04	1.88E+04	8.169	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.61E+04	1.61E+04	6.974	**Th-234**	3.69E-06	3.40E-06	0
Nb-95	1.16E+04	1.16E+04	5.045	**Pa-233**	8.48E-05	1.53E-04	0
Ru-103	1.15E+04	1.16E+04	5.049	**Pa-234m**	3.69E-06	3.73E-06	0
Rh-103m	1.03E+04	9.33E+03	4.053	**U-232**	3.37E-07	1.12E-07	0
Nd-147	7.31E+03	1.19E+04	5.158	**U-234**	5.58E-04	1.55E-04	0
Pr-144	5.03E+03	5.03E+03	2.188	**U-235**	2.68E-04	1.33E-04	0
Ce-144	5.03E+03	5.85E+03	2.541	**U-236**	7.33E-04	1.91E-04	0
Te-132	1.85E+03	2.33E+03	1.014	**U-237**	2.23E+03	4.99E+03	2.167
Mo-99	1.47E+03	1.50E+03	0.652	**U-238**	4.35E-06	9.97E-07	0
Tc-99m	1.42E+03	1.56E+02	0.068	**Np-235**	1.41E-06	4.53E-08	0
Pm-147	4.45E+02	4.45E+02	0.193	**Np-236m**	3.98E-07	2.33E-07	0
Rh-106	2.92E+02	2.92E+02	0.127	**Np-237**	2.04E-04	2.33E-04	0
Ru-106	2.92E+02	0.00E+00	0	**Np-238**	6.36E+00	9.75E+00	0.004
Te-129m	2.88E+02	2.92E+02	0.127	**Np-239**	2.48E+01	5.75E+01	0.025
Pm-148	2.81E+02	2.82E+02	0.122	**Pu-236**	8.79E-05	2.86E-05	0
Te-129	1.87E+02	2.18E+02	0.095	**Pu-237**	4.58E-05	4.03E-06	0
Eu-156	1.77E+02	2.41E+02	0.105	**Pu-238**	2.33E-01	4.06E-02	0
Cs-137	1.62E+02	1.62E+02	0.07	**Pu-239**	3.22E-03	2.52E-04	0
Sr-90	1.56E+02	1.56E+02	0.068	**Pu-240**	1.87E-03	3.09E-04	0
Y-90	1.56E+02	1.56E+02	0.068	**Pu-241**	3.35E-01	2.17E-05	0
Pm-149	1.55E+02	1.55E+02	0.067	**Pu-242**	9.97E-07	1.37E-07	0
Ba-137m	1.53E+02	1.69E+01	0.007	**Am-241**	3.49E-05	2.56E-05	0
Te-127	1.51E+02	1.51E+02	0.066	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.42E+02	1.06E+02	0.046	**Am-242**	5.49E-07	5.61E-07	0
Sb-127	1.11E+02	1.17E+02	0.051	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.22E+01	5.33E+01	0.023	**Cm-242**	2.09E-03	3.28E-04	0
Pr-144m	6.04E+01	4.17E+01	0.018	**Cm-244**	6.00E-05	4.04E-06	0
Pm-148m	5.98E+01	6.90E+01	0.03				
Cs-136	5.02E+01	6.59E+01	0.029	**Total**	2.13E+05	2.30E+05	100

Table C.1 Day 16 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.50E+04	2.57E+04	11.543	**Te-127m**	4.59E+01	4.70E+01	0.021
Pr-143	2.35E+04	2.35E+04	10.549	**Ag-111**	3.75E+01	3.76E+01	0.017
Ce-141	2.32E+04	2.87E+04	12.898	**Sn-125**	3.32E+01	3.31E+01	0.015
Ba-140	2.17E+04	2.58E+04	11.606	**Ce-143**	2.05E+01	2.48E+01	0.011
Zr-95	1.92E+04	1.92E+04	8.642	**Th-231**	2.68E-04	5.71E-04	0
Y-91	1.86E+04	1.86E+04	8.358	**Th-234**	3.71E-06	3.42E-06	0
Sr-89	1.58E+04	1.58E+04	7.121	**Pa-233**	8.79E-05	1.58E-04	0
Nb-95	1.17E+04	1.18E+04	5.29	**Pa-234m**	3.71E-06	3.75E-06	0
Ru-103	1.13E+04	1.14E+04	5.133	**U-232**	3.39E-07	1.13E-07	0
Rh-103m	1.02E+04	9.16E+03	4.123	**U-234**	5.58E-04	1.55E-04	0
Nd-147	6.87E+03	1.12E+04	5.016	**U-235**	2.68E-04	1.33E-04	0
Pr-144	5.02E+03	5.02E+03	2.259	**U-236**	7.33E-04	1.91E-04	0
Ce-144	5.02E+03	5.83E+03	2.624	**U-237**	2.01E+03	4.50E+03	2.025
Te-132	1.50E+03	1.89E+03	0.848	**U-238**	4.35E-06	9.97E-07	0
Mo-99	1.14E+03	1.17E+03	0.525	**Np-235**	1.41E-06	4.52E-08	0
Tc-99m	1.10E+03	1.22E+02	0.055	**Np-237**	2.06E-04	2.35E-04	0
Pm-147	4.49E+02	4.49E+02	0.202	**Np-238**	4.59E+00	7.03E+00	0.003
Rh-106	2.91E+02	2.91E+02	0.131	**Np-239**	1.85E+01	4.29E+01	0.019
Ru-106	2.91E+02	0.00E+00	0	**Pu-236**	8.78E-05	2.86E-05	0
Te-129m	2.82E+02	2.86E+02	0.128	**Pu-237**	4.51E-05	3.97E-06	0
Pm-148	2.47E+02	2.48E+02	0.112	**Pu-238**	2.33E-01	4.06E-02	0
Te-129	1.84E+02	2.14E+02	0.096	**Pu-239**	3.22E-03	2.52E-04	0
Eu-156	1.69E+02	2.31E+02	0.104	**Pu-240**	1.87E-03	3.09E-04	0
Cs-137	1.62E+02	1.62E+02	0.073	**Pu-241**	3.34E-01	2.17E-05	0
Y-90	1.56E+02	1.56E+02	0.07	**Pu-242**	9.97E-07	1.37E-07	0
Sr-90	1.56E+02	1.56E+02	0.07	**Am-241**	3.64E-05	2.67E-05	0
Ba-137m	1.53E+02	1.69E+01	0.008	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.41E+02	1.05E+02	0.047	**Am-242**	5.41E-07	5.53E-07	0
Te-127	1.34E+02	1.34E+02	0.06	**Am-243**	2.46E-06	7.67E-07	0
Pm-149	1.13E+02	1.13E+02	0.051	**Cm-242**	2.08E-03	3.27E-04	0
Sb-127	9.26E+01	9.78E+01	0.044	**Cm-243**	2.24E-07	2.85E-07	0
Cs-134	7.21E+01	5.32E+01	0.024	**Cm-244**	6.00E-05	4.04E-06	0
Pr-144m	6.03E+01	4.16E+01	0.019				
Pm-148m	5.88E+01	6.78E+01	0.031				
Cs-136	4.76E+01	6.25E+01	0.028	**Total**	2.06E+05	2.22E+05	100

Table C.1 Day 17 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.36E+04	2.43E+04	11.307	**Te-127m**	4.56E+01	4.68E+01	0.022
Ce-141	2.27E+04	2.81E+04	13.051	**Cs-136**	4.51E+01	5.93E+01	0.028
Pr-143	2.23E+04	2.23E+04	10.363	**Ag-111**	3.42E+01	3.42E+01	0.016
Ba-140	2.06E+04	2.44E+04	11.367	**Sn-125**	3.09E+01	3.08E+01	0.014
Zr-95	1.90E+04	1.90E+04	8.842	**Th-231**	2.68E-04	5.71E-04	0
Y-91	1.84E+04	1.84E+04	8.54	**Th-234**	3.73E-06	3.43E-06	0
Sr-89	1.56E+04	1.56E+04	7.265	**Pa-233**	9.09E-05	1.64E-04	0
Nb-95	1.19E+04	1.19E+04	5.535	**Pa-234m**	3.73E-06	3.77E-06	0
Ru-103	1.11E+04	1.12E+04	5.214	**U-232**	3.41E-07	1.14E-07	0
Rh-103m	9.99E+03	9.00E+03	4.188	**U-234**	5.58E-04	1.55E-04	0
Nd-147	6.45E+03	1.05E+04	4.87	**U-235**	2.68E-04	1.33E-04	0
Pr-144	5.01E+03	5.01E+03	2.33	**U-236**	7.33E-04	1.91E-04	0
Ce-144	5.01E+03	5.82E+03	2.707	**U-237**	1.82E+03	4.06E+03	1.889
Te-132	1.21E+03	1.53E+03	0.709	**U-238**	4.35E-06	9.97E-07	0
Mo-99	8.88E+02	9.07E+02	0.422	**Np-235**	1.40E-06	4.51E-08	0
Tc-99m	8.56E+02	9.44E+01	0.044	**Np-237**	2.08E-04	2.37E-04	0
Pm-147	4.54E+02	4.54E+02	0.211	**Np-238**	3.31E+00	5.06E+00	0.002
Rh-106	2.90E+02	2.91E+02	0.135	**Np-239**	1.38E+01	3.19E+01	0.015
Ru-106	2.90E+02	0.00E+00	0	**Pu-236**	8.78E-05	2.86E-05	0
Te-129m	2.76E+02	2.80E+02	0.13	**Pu-237**	4.44E-05	3.91E-06	0
Pm-148	2.18E+02	2.18E+02	0.102	**Pu-238**	2.33E-01	4.06E-02	0
Te-129	1.80E+02	2.09E+02	0.097	**Pu-239**	3.23E-03	2.52E-04	0
Eu-156	1.62E+02	2.20E+02	0.103	**Pu-240**	1.87E-03	3.09E-04	0
Cs-137	1.61E+02	1.61E+02	0.075	**Pu-241**	3.34E-01	2.17E-05	0
Y-90	1.56E+02	1.56E+02	0.073	**Pu-242**	9.97E-07	1.37E-07	0
Sr-90	1.56E+02	1.56E+02	0.073	**Am-241**	3.79E-05	2.78E-05	0
Ba-137m	1.53E+02	1.69E+01	0.008	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.40E+02	1.04E+02	0.048	**Am-242**	5.38E-07	5.50E-07	0
Te-127	1.19E+02	1.19E+02	0.055	**Am-243**	2.46E-06	7.67E-07	0
Pm-149	8.26E+01	8.29E+01	0.039	**Cm-242**	2.07E-03	3.25E-04	0
Sb-127	7.74E+01	8.17E+01	0.038	**Cm-243**	2.24E-07	2.85E-07	0
Cs-134	7.21E+01	5.32E+01	0.025	**Cm-244**	6.00E-05	4.04E-06	0
Pr-144m	6.01E+01	4.15E+01	0.019				
Pm-148m	5.78E+01	6.67E+01	0.031	**Total**	2.00E+05	2.15E+05	100

Table C.1 Day 18 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.24E+04	2.30E+04	11.062	**Te-127m**	4.54E+01	4.66E+01	0.022
Ce-141	2.23E+04	2.75E+04	13.195	**Cs-136**	4.28E+01	5.63E+01	0.027
Pr-143	2.12E+04	2.12E+04	10.169	**Ag-111**	3.11E+01	3.12E+01	0.015
Ba-140	1.95E+04	2.32E+04	11.12	**Sn-125**	2.88E+01	2.87E+01	0.014
Zr-95	1.88E+04	1.88E+04	9.03	**Th-231**	2.68E-04	5.71E-04	0
Y-91	1.81E+04	1.81E+04	8.713	**Th-234**	3.75E-06	3.45E-06	0
Sr-89	1.54E+04	1.54E+04	7.397	**Pa-233**	9.39E-05	1.69E-04	0
Nb-95	1.20E+04	1.20E+04	5.783	**Pa-234m**	3.75E-06	3.78E-06	0
Ru-103	1.09E+04	1.10E+04	5.293	**U-232**	3.44E-07	1.14E-07	0
Rh-103m	9.81E+03	8.85E+03	4.249	**U-234**	5.58E-04	1.55E-04	0
Nd-147	6.06E+03	9.83E+03	4.723	**U-235**	2.68E-04	1.33E-04	0
Pr-144	5.00E+03	5.00E+03	2.401	**U-236**	7.33E-04	1.91E-04	0
Ce-144	5.00E+03	5.80E+03	2.788	**U-237**	1.64E+03	3.67E+03	1.76
Te-132	9.78E+02	1.23E+03	0.592	**U-238**	4.35E-06	9.97E-07	0
Mo-99	6.90E+02	7.05E+02	0.338	**Np-235**	1.40E-06	4.51E-08	0
Tc-99m	6.65E+02	7.34E+01	0.035	**Np-237**	2.09E-04	2.38E-04	0
Pm-147	4.58E+02	4.58E+02	0.22	**Np-238**	2.38E+00	3.65E+00	0.002
Rh-106	2.90E+02	2.90E+02	0.139	**Np-239**	1.02E+01	2.38E+01	0.011
Ru-106	2.90E+02	0.00E+00	0	**Pu-236**	8.77E-05	2.86E-05	0
Te-129m	2.71E+02	2.74E+02	0.132	**Pu-237**	4.38E-05	3.85E-06	0
Pm-148	1.92E+02	1.92E+02	0.092	**Pu-238**	2.33E-01	4.06E-02	0
Te-129	1.76E+02	2.05E+02	0.098	**Pu-239**	3.23E-03	2.52E-04	0
Cs-137	1.61E+02	1.61E+02	0.078	**Pu-240**	1.87E-03	3.09E-04	0
Y-90	1.56E+02	1.56E+02	0.075	**Pu-241**	3.34E-01	2.17E-05	0
Sr-90	1.56E+02	1.56E+02	0.075	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	1.54E+02	2.11E+02	0.101	**Am-241**	3.93E-05	2.89E-05	0
Ba-137m	1.53E+02	1.69E+01	0.008	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.38E+02	1.03E+02	0.049	**Am-242**	5.37E-07	5.49E-07	0
Te-127	1.06E+02	1.06E+02	0.051	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.20E+01	5.31E+01	0.026	**Cm-242**	2.06E-03	3.24E-04	0
Sb-127	6.46E+01	6.83E+01	0.033	**Cm-243**	2.24E-07	2.85E-07	0
Pm-149	6.04E+01	6.06E+01	0.029	**Cm-244**	6.00E-05	4.03E-06	0
Pr-144m	6.00E+01	4.14E+01	0.02				
Pm-148m	5.69E+01	6.56E+01	0.031	**Total**	1.94E+05	2.08E+05	100

Table C.1 Day 19 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	2.18E+04	2.69E+04	13.325	**Pm-149**	4.42E+01	4.43E+01	0.022
La-140	2.12E+04	2.18E+04	10.813	**Cs-136**	4.06E+01	5.34E+01	0.026
Pr-143	2.01E+04	2.01E+04	9.97	**Ag-111**	2.84E+01	2.84E+01	0.014
Zr-95	1.86E+04	1.86E+04	9.217	**Sn-125**	2.68E+01	2.67E+01	0.013
Ba-140	1.84E+04	2.19E+04	10.867	**Th-231**	2.68E-04	5.71E-04	0
Y-91	1.79E+04	1.79E+04	8.885	**Th-234**	3.76E-06	3.46E-06	0
Sr-89	1.52E+04	1.52E+04	7.527	**Pa-233**	9.68E-05	1.74E-04	0
Nb-95	1.22E+04	1.22E+04	6.031	**Pa-234m**	3.76E-06	3.80E-06	0
Ru-103	1.07E+04	1.08E+04	5.362	**U-232**	3.46E-07	1.15E-07	0
Rh-103m	9.64E+03	8.69E+03	4.307	**U-234**	5.58E-04	1.55E-04	0
Nd-147	5.69E+03	9.24E+03	4.576	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.99E+03	4.99E+03	2.471	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.99E+03	5.79E+03	2.869	**U-237**	1.48E+03	3.31E+03	1.639
Te-132	7.91E+02	9.97E+02	0.494	**U-238**	4.35E-06	9.97E-07	0
Mo-99	5.37E+02	5.48E+02	0.271	**Np-235**	1.40E-06	4.50E-08	0
Tc-99m	5.17E+02	5.70E+01	0.028	**Np-237**	2.11E-04	2.40E-04	0
Pm-147	4.62E+02	4.62E+02	0.229	**Np-238**	1.72E+00	2.63E+00	0.001
Rh-106	2.89E+02	2.90E+02	0.144	**Np-239**	7.63E+00	1.77E+01	0.009
Ru-106	2.89E+02	0.00E+00	0	**Pu-236**	8.76E-05	2.86E-05	0
Te-129m	2.65E+02	2.69E+02	0.133	**Pu-237**	4.31E-05	3.80E-06	0
Te-129	1.73E+02	2.01E+02	0.1	**Pu-238**	2.33E-01	4.06E-02	0
Pm-148	1.69E+02	1.69E+02	0.084	**Pu-239**	3.23E-03	2.52E-04	0
Cs-137	1.61E+02	1.61E+02	0.08	**Pu-240**	1.87E-03	3.09E-04	0
Y-90	1.56E+02	1.56E+02	0.077	**Pu-241**	3.34E-01	2.17E-05	0
Sr-90	1.56E+02	1.56E+02	0.077	**Pu-242**	9.97E-07	1.37E-07	0
Ba-137m	1.53E+02	1.69E+01	0.008	**Am-241**	4.08E-05	2.99E-05	0
Eu-156	1.48E+02	2.01E+02	0.1	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.37E+02	1.02E+02	0.05	**Am-242**	5.37E-07	5.48E-07	0
Te-127	9.59E+01	9.60E+01	0.048	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.19E+01	5.31E+01	0.026	**Cm-242**	2.05E-03	3.23E-04	0
Pr-144m	5.98E+01	4.13E+01	0.02	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148m	5.59E+01	6.45E+01	0.032	**Cm-244**	6.00E-05	4.03E-06	0
Sb-127	5.40E+01	5.70E+01	0.028				
Te-127m	4.52E+01	4.63E+01	0.023	**Total**	1.88E+05	2.02E+05	100

Table C.1 Day 20 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	2.13E+04	2.63E+04	13.445	**Cs-136**	3.85E+01	5.06E+01	0.026
La-140	2.01E+04	2.07E+04	10.559	**Pm-149**	3.23E+01	3.24E+01	0.017
Pr-143	1.91E+04	1.91E+04	9.762	**Ag-111**	2.58E+01	2.59E+01	0.013
Zr-95	1.84E+04	1.84E+04	9.399	**Sn-125**	2.49E+01	2.48E+01	0.013
Y-91	1.77E+04	1.77E+04	9.052	**Th-231**	2.68E-04	5.71E-04	0
Ba-140	1.75E+04	2.08E+04	10.61	**Th-234**	3.78E-06	3.48E-06	0
Sr-89	1.50E+04	1.50E+04	7.657	**Pa-233**	9.97E-05	1.80E-04	0
Nb-95	1.23E+04	1.23E+04	6.278	**Pa-234m**	3.78E-06	3.82E-06	0
Ru-103	1.05E+04	1.06E+04	5.43	**U-232**	3.48E-07	1.16E-07	0
Rh-103m	9.47E+03	8.54E+03	4.363	**U-234**	5.58E-04	1.55E-04	0
Nd-147	5.35E+03	8.67E+03	4.431	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.97E+03	4.97E+03	2.54	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.97E+03	5.78E+03	2.951	**U-237**	1.34E+03	2.99E+03	1.525
Te-132	6.39E+02	8.06E+02	0.411	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.66E+02	4.66E+02	0.238	**Np-235**	1.40E-06	4.49E-08	0
Mo-99	4.17E+02	4.26E+02	0.217	**Np-237**	2.12E-04	2.41E-04	0
Tc-99m	4.02E+02	4.43E+01	0.023	**Np-238**	1.24E+00	1.90E+00	0.001
Rh-106	2.89E+02	2.89E+02	0.148	**Np-239**	5.69E+00	1.32E+01	0.007
Ru-106	2.89E+02	0.00E+00	0	**Pu-236**	8.76E-05	2.85E-05	0
Te-129m	2.60E+02	2.63E+02	0.134	**Pu-237**	4.25E-05	3.74E-06	0
Te-129	1.69E+02	1.97E+02	0.1	**Pu-238**	2.33E-01	4.06E-02	0
Cs-137	1.61E+02	1.61E+02	0.082	**Pu-239**	3.23E-03	2.52E-04	0
Y-90	1.56E+02	1.56E+02	0.08	**Pu-240**	1.87E-03	3.09E-04	0
Sr-90	1.56E+02	1.56E+02	0.08	**Pu-241**	3.34E-01	2.17E-05	0
Ba-137m	1.53E+02	1.69E+01	0.009	**Pu-242**	9.97E-07	1.37E-07	0
Pm-148	1.49E+02	1.49E+02	0.076	**Am-241**	4.23E-05	3.10E-05	0
Eu-156	1.41E+02	1.92E+02	0.098	**Am-242m**	5.39E-07	5.39E-07	0
Nb-95m	1.36E+02	1.01E+02	0.051	**Am-242**	5.37E-07	5.48E-07	0
Te-127	8.72E+01	8.72E+01	0.045	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.19E+01	5.30E+01	0.027	**Cm-242**	2.05E-03	3.21E-04	0
Pr-144m	5.97E+01	4.12E+01	0.021	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148m	5.50E+01	6.34E+01	0.032	**Cm-244**	6.00E-05	4.03E-06	0
Sb-127	4.51E+01	4.76E+01	0.024				
Te-127m	4.49E+01	4.61E+01	0.024	**Total**	1.82E+05	1.96E+05	100

Table C.1 Day 21 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	2.09E+04	2.58E+04	13.558	**Cs-136**	3.65E+01	4.80E+01	0.025
La-140	1.90E+04	1.96E+04	10.301	**Pm-149**	2.36E+01	2.37E+01	0.012
Zr-95	1.82E+04	1.82E+04	9.575	**Ag-111**	2.35E+01	2.36E+01	0.012
Pr-143	1.82E+04	1.82E+04	9.554	**Sn-125**	2.32E+01	2.31E+01	0.012
Y-91	1.75E+04	1.75E+04	9.212	**Th-231**	2.68E-04	5.71E-04	0
Ba-140	1.65E+04	1.97E+04	10.354	**Th-234**	3.80E-06	3.49E-06	0
Sr-89	1.48E+04	1.48E+04	7.776	**Pa-233**	1.03E-04	1.85E-04	0
Nb-95	1.24E+04	1.24E+04	6.529	**Pa-234m**	3.80E-06	3.83E-06	0
Ru-103	1.03E+04	1.05E+04	5.498	**U-232**	3.51E-07	1.17E-07	0
Rh-103m	9.30E+03	8.39E+03	4.414	**U-234**	5.58E-04	1.55E-04	0
Nd-147	5.02E+03	8.15E+03	4.286	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.96E+03	4.96E+03	2.61	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.96E+03	5.76E+03	3.031	**U-237**	1.20E+03	2.69E+03	1.417
Te-132	5.17E+02	6.51E+02	0.343	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.69E+02	4.69E+02	0.247	**Np-235**	1.39E-06	4.48E-08	0
Mo-99	3.24E+02	3.31E+02	0.174	**Np-237**	2.13E-04	2.43E-04	0
Tc-99m	3.12E+02	3.45E+01	0.018	**Np-238**	8.92E-01	1.37E+00	0.001
Rh-106	2.88E+02	2.89E+02	0.152	**Np-239**	4.24E+00	9.84E+00	0.005
Ru-106	2.88E+02	0.00E+00	0	**Pu-236**	8.75E-05	2.85E-05	0
Te-129m	2.54E+02	2.58E+02	0.136	**Pu-237**	4.18E-05	3.68E-06	0
Te-129	1.66E+02	1.93E+02	0.101	**Pu-238**	2.33E-01	4.06E-02	0
Cs-137	1.61E+02	1.61E+02	0.085	**Pu-239**	3.23E-03	2.52E-04	0
Y-90	1.56E+02	1.56E+02	0.082	**Pu-240**	1.87E-03	3.09E-04	0
Sr-90	1.56E+02	1.56E+02	0.082	**Pu-241**	3.34E-01	2.17E-05	0
Ba-137m	1.53E+02	1.69E+01	0.009	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	1.35E+02	1.84E+02	0.097	**Am-241**	4.37E-05	3.21E-05	0
Nb-95m	1.34E+02	9.96E+01	0.052	**Am-242m**	5.39E-07	5.39E-07	0
Pm-148	1.31E+02	1.31E+02	0.069	**Am-242**	5.37E-07	5.48E-07	0
Te-127	7.98E+01	7.99E+01	0.042	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.18E+01	5.30E+01	0.028	**Cm-242**	2.04E-03	3.20E-04	0
Pr-144m	5.95E+01	4.11E+01	0.022	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148m	5.41E+01	6.24E+01	0.033	**Cm-244**	6.00E-05	4.03E-06	0
Te-127m	4.47E+01	4.58E+01	0.024				
Sb-127	3.77E+01	3.98E+01	0.021	**Total**	1.77E+05	1.90E+05	100

Table C.1 Day 22 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	2.04E+04	2.52E+04	13.661	**Sb-127**	3.14E+01	3.32E+01	0.018
La-140	1.80E+04	1.85E+04	10.039	**Sn-125**	2.16E+01	2.15E+01	0.012
Zr-95	1.80E+04	1.80E+04	9.752	**Ag-111**	2.15E+01	2.15E+01	0.012
Y-91	1.73E+04	1.73E+04	9.367	**Pm-149**	1.72E+01	1.73E+01	0.009
Pr-143	1.73E+04	1.73E+04	9.346	**Th-231**	2.68E-04	5.71E-04	0
Ba-140	1.57E+04	1.86E+04	10.093	**Th-234**	3.81E-06	3.51E-06	0
Sr-89	1.46E+04	1.46E+04	7.894	**Pa-233**	1.05E-04	1.90E-04	0
Nb-95	1.25E+04	1.25E+04	6.779	**Pa-234m**	3.81E-06	3.85E-06	0
Ru-103	1.01E+04	1.03E+04	5.561	**U-232**	3.53E-07	1.17E-07	0
Rh-103m	9.14E+03	8.24E+03	4.464	**U-234**	5.58E-04	1.55E-04	0
Pr-144	4.95E+03	4.95E+03	2.68	**U-235**	2.68E-04	1.33E-04	0
Ce-144	4.95E+03	5.75E+03	3.112	**U-236**	7.33E-04	1.91E-04	0
Nd-147	4.72E+03	7.65E+03	4.143	**U-237**	1.09E+03	2.43E+03	1.316
Pm-147	4.72E+02	4.72E+02	0.256	**U-238**	4.35E-06	9.97E-07	0
Te-132	4.18E+02	5.26E+02	0.285	**Np-235**	1.39E-06	4.47E-08	0
Rh-106	2.88E+02	2.88E+02	0.156	**Np-237**	2.14E-04	2.44E-04	0
Ru-106	2.88E+02	0.00E+00	0	**Np-238**	6.43E-01	9.85E-01	0.001
Mo-99	2.52E+02	2.57E+02	0.139	**Np-239**	3.16E+00	7.33E+00	0.004
Te-129m	2.49E+02	2.52E+02	0.137	**Pu-236**	8.75E-05	2.85E-05	0
Tc-99m	2.43E+02	2.68E+01	0.015	**Pu-237**	4.12E-05	3.63E-06	0
Te-129	1.62E+02	1.89E+02	0.102	**Pu-238**	2.33E-01	4.06E-02	0
Cs-137	1.61E+02	1.61E+02	0.087	**Pu-239**	3.23E-03	2.52E-04	0
Y-90	1.56E+02	1.56E+02	0.085	**Pu-240**	1.87E-03	3.09E-04	0
Sr-90	1.56E+02	1.56E+02	0.085	**Pu-241**	3.34E-01	2.17E-05	0
Ba-137m	1.53E+02	1.69E+01	0.009	**Pu-242**	9.97E-07	1.37E-07	0
Nb-95m	1.33E+02	9.86E+01	0.053	**Am-241**	4.52E-05	3.32E-05	0
Eu-156	1.29E+02	1.75E+02	0.095	**Am-242m**	5.39E-07	5.39E-07	0
Pm-148	1.16E+02	1.16E+02	0.063	**Am-242**	5.37E-07	5.48E-07	0
Te-127	7.36E+01	7.37E+01	0.04	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.17E+01	5.29E+01	0.029	**Cm-242**	2.03E-03	3.19E-04	0
Pr-144m	5.94E+01	4.10E+01	0.022	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148m	5.32E+01	6.13E+01	0.033	**Cm-244**	6.00E-05	4.03E-06	0
Te-127m	4.44E+01	4.56E+01	0.025				
Cs-136	3.46E+01	4.55E+01	0.025	**Total**	1.73E+05	1.85E+05	100

Table C.1 Day 23 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	2.00E+04	2.47E+04	13.75	**Sb-127**	2.63E+01	2.77E+01	0.015
Zr-95	1.78E+04	1.78E+04	9.918	**Sn-125**	2.01E+01	2.00E+01	0.011
Y-91	1.71E+04	1.71E+04	9.523	**Ag-111**	1.95E+01	1.96E+01	0.011
La-140	1.71E+04	1.76E+04	9.785	**Th-231**	2.68E-04	5.71E-04	0
Pr-143	1.64E+04	1.64E+04	9.133	**Th-234**	3.83E-06	3.52E-06	0
Ba-140	1.48E+04	1.77E+04	9.835	**Pa-233**	1.08E-04	1.95E-04	0
Sr-89	1.44E+04	1.44E+04	8.008	**Pa-234m**	3.83E-06	3.87E-06	0
Nb-95	1.26E+04	1.26E+04	7.034	**U-232**	3.55E-07	1.18E-07	0
Ru-103	9.96E+03	1.01E+04	5.619	**U-234**	5.58E-04	1.55E-04	0
Rh-103m	8.98E+03	8.10E+03	4.51	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.94E+03	4.94E+03	2.749	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.94E+03	5.73E+03	3.193	**U-237**	9.81E+02	2.19E+03	1.221
Nd-147	4.43E+03	7.19E+03	4.002	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.75E+02	4.75E+02	0.265	**Np-235**	1.39E-06	4.47E-08	0
Te-132	3.38E+02	4.26E+02	0.237	**Np-237**	2.15E-04	2.45E-04	0
Rh-106	2.87E+02	2.88E+02	0.16	**Np-238**	4.63E-01	7.10E-01	0
Ru-106	2.87E+02	0.00E+00	0	**Np-239**	2.35E+00	5.46E+00	0.003
Te-129m	2.44E+02	2.47E+02	0.138	**Pu-236**	8.74E-05	2.85E-05	0
Mo-99	1.96E+02	2.00E+02	0.111	**Pu-237**	4.06E-05	3.57E-06	0
Tc-99m	1.89E+02	2.08E+01	0.012	**Pu-238**	2.33E-01	4.06E-02	0
Cs-137	1.61E+02	1.61E+02	0.09	**Pu-239**	3.23E-03	2.52E-04	0
Te-129	1.59E+02	1.85E+02	0.103	**Pu-240**	1.87E-03	3.09E-04	0
Y-90	1.56E+02	1.56E+02	0.087	**Pu-241**	3.34E-01	2.17E-05	0
Sr-90	1.56E+02	1.56E+02	0.087	**Pu-242**	9.97E-07	1.37E-07	0
Ba-137m	1.53E+02	1.69E+01	0.009	**Am-241**	4.67E-05	3.42E-05	0
Nb-95m	1.32E+02	9.76E+01	0.054	**Am-242m**	5.39E-07	5.39E-07	0
Eu-156	1.23E+02	1.68E+02	0.093	**Am-242**	5.37E-07	5.48E-07	0
Pm-148	1.02E+02	1.02E+02	0.057	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.17E+01	5.29E+01	0.029	**Cm-242**	2.02E-03	3.17E-04	0
Te-127	6.84E+01	6.85E+01	0.038	**Cm-243**	2.24E-07	2.85E-07	0
Pr-144m	5.92E+01	4.09E+01	0.023	**Cm-244**	6.00E-05	4.03E-06	0
Pm-148m	5.23E+01	6.03E+01	0.034				
Te-127m	4.42E+01	4.53E+01	0.025				
Cs-136	3.29E+01	4.32E+01	0.024	**Total**	1.68E+05	1.80E+05	100

Table C.1 Day 24 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.96E+04	2.42E+04	13.836	**Sb-127**	2.19E+01	2.32E+01	0.013
Zr-95	1.76E+04	1.76E+04	10.086	**Sn-125**	1.87E+01	1.86E+01	0.011
Y-91	1.69E+04	1.69E+04	9.674	**Ag-111**	1.78E+01	1.79E+01	0.01
La-140	1.62E+04	1.66E+04	9.525	**Th-231**	2.68E-04	5.71E-04	0
Pr-143	1.56E+04	1.56E+04	8.919	**Th-234**	3.84E-06	3.54E-06	0
Sr-89	1.42E+04	1.42E+04	8.117	**Pa-233**	1.11E-04	2.00E-04	0
Ba-140	1.41E+04	1.67E+04	9.571	**Pa-234m**	3.84E-06	3.88E-06	0
Nb-95	1.27E+04	1.27E+04	7.287	**U-232**	3.58E-07	1.19E-07	0
Ru-103	9.79E+03	9.91E+03	5.673	**U-234**	5.58E-04	1.55E-04	0
Rh-103m	8.83E+03	7.96E+03	4.555	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.93E+03	4.93E+03	2.819	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.93E+03	5.72E+03	3.274	**U-237**	8.85E+02	1.98E+03	1.133
Nd-147	4.16E+03	6.75E+03	3.865	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.78E+02	4.78E+02	0.274	**Np-235**	1.39E-06	4.46E-08	0
Rh-106	2.87E+02	2.87E+02	0.164	**Np-237**	2.16E-04	2.46E-04	0
Ru-106	2.87E+02	0.00E+00	0	**Np-238**	3.34E-01	5.12E-01	0
Te-132	2.73E+02	3.44E+02	0.197	**Np-239**	1.75E+00	4.07E+00	0.002
Te-129m	2.39E+02	2.42E+02	0.139	**Pu-236**	8.73E-05	2.85E-05	0
Cs-137	1.61E+02	1.61E+02	0.092	**Pu-237**	4.00E-05	3.52E-06	0
Y-90	1.56E+02	1.56E+02	0.089	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.089	**Pu-239**	3.23E-03	2.52E-04	0
Te-129	1.56E+02	1.81E+02	0.104	**Pu-240**	1.87E-03	3.09E-04	0
Ba-137m	1.53E+02	1.69E+01	0.01	**Pu-241**	3.34E-01	2.17E-05	0
Mo-99	1.52E+02	1.55E+02	0.089	**Pu-242**	9.97E-07	1.37E-07	0
Tc-99m	1.47E+02	1.62E+01	0.009	**Am-241**	4.81E-05	3.53E-05	0
Nb-95m	1.30E+02	9.66E+01	0.055	**Am-242m**	5.39E-07	5.39E-07	0
Eu-156	1.17E+02	1.60E+02	0.092	**Am-242**	5.37E-07	5.48E-07	0
Pm-148	8.98E+01	9.00E+01	0.052	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.16E+01	5.29E+01	0.03	**Cm-242**	2.01E-03	3.16E-04	0
Te-127	6.40E+01	6.41E+01	0.037	**Cm-243**	2.24E-07	2.85E-07	0
Pr-144m	5.91E+01	4.08E+01	0.023	**Cm-244**	6.00E-05	4.03E-06	0
Pm-148m	5.14E+01	5.93E+01	0.034				
Te-127m	4.39E+01	4.50E+01	0.026				
Cs-136	3.12E+01	4.10E+01	0.023	**Total**	1.64E+05	1.75E+05	100

Table C.1 Day 25 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.92E+04	2.37E+04	13.912	**Sb-127**	1.83E+01	1.94E+01	0.011
Zr-95	1.74E+04	1.74E+04	10.249	**Sn-125**	1.74E+01	1.73E+01	0.01
Y-91	1.67E+04	1.67E+04	9.82	**Ag-111**	1.62E+01	1.63E+01	0.01
La-140	1.53E+04	1.58E+04	9.267	**Th-231**	2.68E-04	5.71E-04	0
Pr-143	1.48E+04	1.48E+04	8.703	**Th-234**	3.86E-06	3.55E-06	0
Sr-89	1.40E+04	1.40E+04	8.226	**Pa-233**	1.14E-04	2.04E-04	0
Ba-140	1.33E+04	1.58E+04	9.314	**Pa-234m**	3.86E-06	3.90E-06	0
Nb-95	1.28E+04	1.28E+04	7.538	**U-232**	3.60E-07	1.20E-07	0
Ru-103	9.62E+03	9.74E+03	5.725	**U-234**	5.58E-04	1.55E-04	0
Rh-103m	8.67E+03	7.82E+03	4.598	**U-235**	2.68E-04	1.33E-04	0
Pr-144	4.91E+03	4.91E+03	2.889	**U-236**	7.33E-04	1.91E-04	0
Ce-144	4.91E+03	5.71E+03	3.355	**U-237**	7.99E+02	1.79E+03	1.05
Nd-147	3.91E+03	6.34E+03	3.729	**U-238**	4.35E-06	9.97E-07	0
Pm-147	4.81E+02	4.81E+02	0.283	**Np-235**	1.38E-06	4.45E-08	0
Rh-106	2.86E+02	2.87E+02	0.168	**Np-237**	2.17E-04	2.47E-04	0
Ru-106	2.86E+02	0.00E+00	0	**Np-238**	2.41E-01	3.69E-01	0
Te-129m	2.34E+02	2.37E+02	0.139	**Np-239**	1.31E+00	3.03E+00	0.002
Te-132	2.21E+02	2.78E+02	0.163	**Pu-236**	8.73E-05	2.84E-05	0
Cs-137	1.61E+02	1.61E+02	0.095	**Pu-237**	3.94E-05	3.47E-06	0
Y-90	1.56E+02	1.56E+02	0.092	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.092	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.01	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.53E+02	1.78E+02	0.104	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.29E+02	9.55E+01	0.056	**Pu-242**	9.97E-07	1.37E-07	0
Mo-99	1.18E+02	1.21E+02	0.071	**Am-241**	4.96E-05	3.64E-05	0
Tc-99m	1.14E+02	1.26E+01	0.007	**Am-242m**	5.39E-07	5.39E-07	0
Eu-156	1.12E+02	1.53E+02	0.09	**Am-242**	5.37E-07	5.48E-07	0
Pm-148	7.92E+01	7.94E+01	0.047	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.15E+01	5.28E+01	0.031	**Cm-242**	2.00E-03	3.15E-04	0
Te-127	6.03E+01	6.04E+01	0.035	**Cm-243**	2.24E-07	2.85E-07	0
Pr-144m	5.90E+01	4.07E+01	0.024	**Cm-244**	6.00E-05	4.03E-06	0
Pm-148m	5.06E+01	5.83E+01	0.034				
Te-127m	4.37E+01	4.48E+01	0.026	**Total**	1.60E+05	1.70E+05	100

Table C.1 Day 26 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.88E+04	2.32E+04	13.982	**Cs-136**	2.80E+01	3.68E+01	0.022
Zr-95	1.72E+04	1.72E+04	10.408	**Sn-125**	1.62E+01	1.61E+01	0.01
Y-91	1.65E+04	1.65E+04	9.961	**Th-231**	2.68E-04	5.71E-04	0
La-140	1.45E+04	1.49E+04	9.013	**Th-234**	3.87E-06	3.56E-06	0
Pr-143	1.41E+04	1.41E+04	8.494	**Pa-233**	1.16E-04	2.09E-04	0
Sr-89	1.38E+04	1.38E+04	8.331	**Pa-234m**	3.87E-06	3.91E-06	0
Nb-95	1.29E+04	1.29E+04	7.794	**U-232**	3.62E-07	1.21E-07	0
Ba-140	1.26E+04	1.50E+04	9.062	**U-234**	5.58E-04	1.55E-04	0
Ru-103	9.45E+03	9.57E+03	5.776	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	8.52E+03	7.68E+03	4.638	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.90E+03	4.90E+03	2.959	**U-237**	7.21E+02	1.61E+03	0.973
Ce-144	4.90E+03	5.69E+03	3.436	**U-238**	4.35E-06	9.97E-07	0
Nd-147	3.67E+03	5.96E+03	3.595	**Np-235**	1.38E-06	4.44E-08	0
Pm-147	4.83E+02	4.83E+02	0.292	**Np-237**	2.17E-04	2.47E-04	0
Rh-106	2.86E+02	2.86E+02	0.173	**Np-238**	1.74E-01	2.66E-01	0
Ru-106	2.86E+02	0.00E+00	0	**Np-239**	9.73E-01	2.26E+00	0.001
Te-129m	2.29E+02	2.32E+02	0.14	**Pu-236**	8.72E-05	2.84E-05	0
Te-132	1.78E+02	2.25E+02	0.136	**Pu-237**	3.88E-05	3.41E-06	0
Cs-137	1.61E+02	1.61E+02	0.097	**Pu-238**	2.33E-01	4.06E-02	0
Y-90	1.56E+02	1.56E+02	0.094	**Pu-239**	3.23E-03	2.52E-04	0
Sr-90	1.56E+02	1.56E+02	0.094	**Pu-240**	1.87E-03	3.09E-04	0
Ba-137m	1.53E+02	1.69E+01	0.01	**Pu-241**	3.34E-01	2.17E-05	0
Te-129	1.49E+02	1.74E+02	0.105	**Pu-242**	9.97E-07	1.37E-07	0
Nb-95m	1.28E+02	9.45E+01	0.057	**Am-241**	5.11E-05	3.75E-05	0
Eu-156	1.07E+02	1.46E+02	0.088	**Am-242m**	5.39E-07	5.39E-07	0
Mo-99	9.19E+01	9.38E+01	0.057	**Am-242**	5.37E-07	5.48E-07	0
Tc-99m	8.85E+01	9.77E+00	0.006	**Am-243**	2.46E-06	7.67E-07	0
Cs-134	7.15E+01	5.28E+01	0.032	**Cm-242**	1.99E-03	3.13E-04	0
Pm-148	6.99E+01	7.01E+01	0.042	**Cm-243**	2.24E-07	2.85E-07	0
Pr-144m	5.88E+01	4.06E+01	0.024	**Cm-244**	6.00E-05	4.03E-06	0
Te-127	5.72E+01	5.72E+01	0.035				
Pm-148m	4.97E+01	5.73E+01	0.035				
Te-127m	4.34E+01	4.45E+01	0.027	**Total**	1.56E+05	1.66E+05	100

Table C.1 Day 27 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.84E+04	2.27E+04	14.043	**Te-127m**	4.31E+01	4.42E+01	0.027
Zr-95	1.70E+04	1.71E+04	10.568	**Cs-136**	2.66E+01	3.50E+01	0.022
Y-91	1.63E+04	1.63E+04	10.103	**Th-231**	2.68E-04	5.71E-04	0
La-140	1.38E+04	1.41E+04	8.759	**Th-234**	3.88E-06	3.57E-06	0
Sr-89	1.36E+04	1.36E+04	8.431	**Pa-233**	1.19E-04	2.14E-04	0
Pr-143	1.34E+04	1.34E+04	8.282	**Pa-234m**	3.88E-06	3.92E-06	0
Nb-095	1.30E+04	1.30E+04	8.047	**U-232**	3.64E-07	1.21E-07	0
Ba-140	1.20E+04	1.42E+04	8.809	**U-234**	5.58E-04	1.55E-04	0
Ru-103	9.28E+03	9.40E+03	5.822	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	8.37E+03	7.55E+03	4.675	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.89E+03	4.89E+03	3.029	**U-237**	6.50E+02	1.45E+03	0.901
Ce-144	4.89E+03	5.68E+03	3.517	**U-238**	4.35E-06	9.97E-07	0
Nd-147	3.45E+03	5.59E+03	3.465	**Np-235**	1.38E-06	4.44E-08	0
Pm-147	4.85E+02	4.85E+02	0.301	**Np-237**	2.18E-04	2.48E-04	0
Rh-106	2.85E+02	2.86E+02	0.177	**Np-238**	1.25E-01	1.92E-01	0
Ru-106	2.85E+02	0.00E+00	0	**Np-239**	7.25E-01	1.68E+00	0.001
Te-129m	2.25E+02	2.28E+02	0.141	**Pu-236**	8.72E-05	2.84E-05	0
Cs-137	1.61E+02	1.61E+02	0.1	**Pu-237**	3.82E-05	3.36E-06	0
Y-90	1.56E+02	1.56E+02	0.097	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.097	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.01	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.46E+02	1.70E+02	0.105	**Pu-241**	3.34E-01	2.17E-05	0
Te-132	1.44E+02	1.82E+02	0.113	**Pu-242**	9.97E-07	1.37E-07	0
Nb-95m	1.26E+02	9.36E+01	0.058	**Am-241**	5.25E-05	3.85E-05	0
Eu-156	1.02E+02	1.40E+02	0.086	**Am-242m**	5.39E-07	5.39E-07	0
Mo-99	7.14E+01	7.29E+01	0.045	**Am-242**	5.37E-07	5.48E-07	0
Cs-134	7.14E+01	5.27E+01	0.033	**Am-243**	2.46E-06	7.67E-07	0
Tc-99m	6.88E+01	7.59E+00	0.005	**Cm-242**	1.99E-03	3.12E-04	0
Pm-148	6.17E+01	6.19E+01	0.038	**Cm-243**	2.24E-07	2.85E-07	0
Pr-144m	5.87E+01	4.05E+01	0.025	**Cm-244**	6.00E-05	4.03E-06	0
Te-127	5.45E+01	5.45E+01	0.034				
Pm-148m	4.89E+01	5.64E+01	0.035	**Total**	1.52E+05	1.61E+05	100

Table C.1 Day 28 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.80E+04	2.22E+04	14.102	**Te-127m**	4.29E+01	4.40E+01	0.028
Zr-95	1.69E+04	1.69E+04	10.716	**Cs-136**	2.52E+01	3.32E+01	0.021
Y-91	1.61E+04	1.61E+04	10.233	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.34E+04	1.34E+04	8.531	**Th-234**	3.90E-06	3.59E-06	0
Nb-95	1.31E+04	1.31E+04	8.302	**Pa-233**	1.21E-04	2.18E-04	0
La-140	1.30E+04	1.34E+04	8.512	**Pa-234m**	3.90E-06	3.94E-06	0
Pr-143	1.27E+04	1.27E+04	8.067	**U-232**	3.67E-07	1.22E-07	0
Ba-140	1.13E+04	1.35E+04	8.556	**U-234**	5.58E-04	1.55E-04	0
Ru-103	9.12E+03	9.24E+03	5.866	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	8.22E+03	7.42E+03	4.71	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.88E+03	4.88E+03	3.098	**U-237**	5.87E+02	1.31E+03	0.833
Ce-144	4.88E+03	5.67E+03	3.598	**U-238**	4.35E-06	9.97E-07	0
Nd-147	3.24E+03	5.25E+03	3.337	**Np-235**	1.38E-06	4.43E-08	0
Pm-147	4.87E+02	4.87E+02	0.309	**Np-237**	2.18E-04	2.49E-04	0
Rh-106	2.85E+02	2.85E+02	0.181	**Np-238**	9.01E-02	1.38E-01	0
Ru-106	2.85E+02	0.00E+00	0	**Np-239**	5.40E-01	1.25E+00	0.001
Te-129m	2.20E+02	2.23E+02	0.142	**Pu-236**	8.71E-05	2.84E-05	0
Cs-137	1.61E+02	1.61E+02	0.102	**Pu-237**	3.76E-05	3.31E-06	0
Y-90	1.56E+02	1.56E+02	0.099	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.099	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.011	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.43E+02	1.67E+02	0.106	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.25E+02	9.26E+01	0.059	**Pu-242**	9.97E-07	1.37E-07	0
Te-132	1.17E+02	1.47E+02	0.093	**Am-241**	5.40E-05	3.96E-05	0
Eu-156	9.79E+01	1.33E+02	0.085	**Am-242m**	5.39E-07	5.39E-07	0
Cs-134	7.13E+01	5.27E+01	0.033	**Am-242**	5.37E-07	5.48E-07	0
Pr-144m	5.85E+01	4.04E+01	0.026	**Am-243**	2.46E-06	7.67E-07	0
Mo-99	5.55E+01	5.67E+01	0.036	**Cm-242**	1.98E-03	3.11E-04	0
Pm-148	5.46E+01	5.47E+01	0.035	**Cm-243**	2.24E-07	2.85E-07	0
Tc-99m	5.35E+01	5.90E+00	0.004	**Cm-244**	6.00E-05	4.03E-06	0
Te-127	5.22E+01	5.23E+01	0.033				
Pm-148m	4.81E+01	5.54E+01	0.035	**Total**	1.48E+05	1.57E+05	100

Table C.1 Day 29 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.76E+04	2.17E+04	14.149	**Tc-99m**	4.16E+01	4.59E+00	0.003
Zr-95	1.67E+04	1.67E+04	10.867	**Cs-136**	2.39E+01	3.14E+01	0.02
Y-91	1.59E+04	1.59E+04	10.366	**Th-231**	2.68E-04	5.71E-04	0
Sr-89	1.32E+04	1.32E+04	8.621	**Th-234**	3.91E-06	3.60E-06	0
Nb-95	1.31E+04	1.31E+04	8.556	**Pa-233**	1.24E-04	2.23E-04	0
La-140	1.23E+04	1.27E+04	8.263	**Pa-234m**	3.91E-06	3.95E-06	0
Pr-143	1.21E+04	1.21E+04	7.859	**U-232**	3.69E-07	1.23E-07	0
Ba-140	1.07E+04	1.28E+04	8.302	**U-234**	5.58E-04	1.55E-04	0
Ru-103	8.96E+03	9.07E+03	5.908	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	8.08E+03	7.29E+03	4.744	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.87E+03	4.87E+03	3.168	**U-237**	5.30E+02	1.18E+03	0.771
Ce-144	4.87E+03	5.65E+03	3.68	**U-238**	4.35E-06	9.97E-07	0
Nd-147	3.04E+03	4.94E+03	3.213	**Np-235**	1.37E-06	4.42E-08	0
Pm-147	4.89E+02	4.89E+02	0.318	**Np-237**	2.19E-04	2.49E-04	0
Rh-106	2.84E+02	2.84E+02	0.185	**Np-238**	6.50E-02	9.96E-02	0
Ru-106	2.84E+02	0.00E+00	0	**Np-239**	4.02E-01	9.35E-01	0.001
Te-129m	2.16E+02	2.18E+02	0.142	**Pu-236**	8.71E-05	2.84E-05	0
Cs-137	1.61E+02	1.61E+02	0.105	**Pu-237**	3.70E-05	3.26E-06	0
Y-90	1.56E+02	1.56E+02	0.102	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.102	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.011	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.40E+02	1.63E+02	0.106	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.24E+02	9.16E+01	0.06	**Pu-242**	9.97E-07	1.37E-07	0
Te-132	9.42E+01	1.19E+02	0.077	**Am-241**	5.55E-05	4.07E-05	0
Eu-156	9.35E+01	1.27E+02	0.083	**Am-242m**	5.39E-07	5.39E-07	0
Cs-134	7.13E+01	5.26E+01	0.034	**Am-242**	5.37E-07	5.48E-07	0
Pr-144m	5.84E+01	4.03E+01	0.026	**Am-243**	2.46E-06	7.67E-07	0
Te-127	5.03E+01	5.03E+01	0.033	**Cm-242**	1.97E-03	3.09E-04	0
Pm-148	4.82E+01	4.84E+01	0.031	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148m	4.73E+01	5.45E+01	0.035	**Cm-244**	6.00E-05	4.03E-06	0
Mo-99	4.32E+01	4.40E+01	0.029				
Te-127m	4.26E+01	4.37E+01	0.028	**Total**	1.45E+05	1.54E+05	100

Table C.1 Day 30 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.72E+04	2.13E+04	14.187	**Tc-99m**	3.23E+01	3.57E+00	0.002
Zr-95	1.65E+04	1.65E+04	11.012	**Cs-136**	2.27E+01	2.98E+01	0.02
Y-91	1.57E+04	1.57E+04	10.499	**Th-231**	2.68E-04	5.71E-04	0
Nb-95	1.32E+04	1.32E+04	8.811	**Th-234**	3.92E-06	3.61E-06	0
Sr-89	1.31E+04	1.31E+04	8.711	**Pa-233**	1.26E-04	2.27E-04	0
La-140	1.17E+04	1.20E+04	8.017	**Pa-234m**	3.92E-06	3.96E-06	0
Pr-143	1.15E+04	1.15E+04	7.65	**U-232**	3.71E-07	1.24E-07	0
Ba-140	1.02E+04	1.21E+04	8.057	**U-234**	5.58E-04	1.55E-04	0
Ru-103	8.81E+03	8.92E+03	5.946	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	7.94E+03	7.16E+03	4.774	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.85E+03	4.85E+03	3.238	**U-237**	4.78E+02	1.07E+03	0.713
Ce-144	4.85E+03	5.64E+03	3.76	**U-238**	4.35E-06	9.97E-07	0
Nd-147	2.86E+03	4.64E+03	3.092	**Np-235**	1.37E-06	4.41E-08	0
Pm-147	4.91E+02	4.91E+02	0.327	**Np-237**	2.19E-04	2.50E-04	0
Rh-106	2.83E+02	2.84E+02	0.189	**Np-238**	4.68E-02	7.18E-02	0
Ru-106	2.83E+02	0.00E+00	0	**Np-239**	3.00E-01	6.96E-01	0
Te-129m	2.11E+02	2.14E+02	0.143	**Pu-236**	8.70E-05	2.83E-05	0
Cs-137	1.61E+02	1.61E+02	0.108	**Pu-237**	3.65E-05	3.21E-06	0
Y-90	1.56E+02	1.56E+02	0.104	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.104	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.011	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.38E+02	1.60E+02	0.107	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.22E+02	9.06E+01	0.06	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	8.93E+01	1.22E+02	0.081	**Am-241**	5.69E-05	4.18E-05	0
Te-132	7.62E+01	9.60E+01	0.064	**Am-242m**	5.39E-07	5.39E-07	0
Cs-134	7.12E+01	5.26E+01	0.035	**Am-242**	5.37E-07	5.48E-07	0
Pr-144m	5.82E+01	4.02E+01	0.027	**Am-243**	2.46E-06	7.67E-07	0
Te-127	4.86E+01	4.86E+01	0.032	**Cm-242**	1.96E-03	3.08E-04	0
Pm-148m	4.65E+01	5.36E+01	0.036	**Cm-243**	2.24E-07	2.85E-07	0
Pm-148	4.27E+01	4.28E+01	0.029	**Cm-244**	6.00E-05	4.03E-06	0
Te-127m	4.23E+01	4.34E+01	0.029				
Mo-99	3.35E+01	3.42E+01	0.023	**Total**	1.42E+05	1.50E+05	100

Table C.1 Day 31 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.69E+04	2.08E+04	14.22	**Tc-99m**	2.51E+01	2.77E+00	0.002
Zr-95	1.63E+04	1.63E+04	11.153	**Cs-136**	2.15E+01	2.83E+01	0.019
Y-91	1.56E+04	1.56E+04	10.621	**Th-231**	2.68E-04	5.71E-04	0
Nb-95	1.33E+04	1.33E+04	9.063	**Th-234**	3.93E-06	3.62E-06	0
Sr-89	1.29E+04	1.29E+04	8.804	**Pa-233**	1.29E-04	2.31E-04	0
La-140	1.11E+04	1.14E+04	7.779	**Pa-234m**	3.93E-06	3.97E-06	0
Pr-143	1.09E+04	1.09E+04	7.445	**U-232**	3.74E-07	1.24E-07	0
Ba-140	9.62E+03	1.14E+04	7.814	**U-234**	5.58E-04	1.55E-04	0
Ru-103	8.65E+03	8.76E+03	5.982	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	7.80E+03	7.03E+03	4.804	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.84E+03	4.84E+03	3.307	**U-237**	4.31E+02	9.65E+02	0.659
Ce-144	4.84E+03	5.62E+03	3.841	**U-238**	4.35E-06	9.97E-07	0
Nd-147	2.68E+03	4.35E+03	2.973	**Np-235**	1.37E-06	4.40E-08	0
Pm-147	4.93E+02	4.93E+02	0.336	**Np-237**	2.20E-04	2.50E-04	0
Rh-106	2.83E+02	2.83E+02	0.193	**Np-238**	3.38E-02	5.17E-02	0
Ru-106	2.83E+02	0.00E+00	0	**Np-239**	2.23E-01	5.19E-01	0
Te-129m	2.07E+02	2.10E+02	0.143	**Pu-236**	8.69E-05	2.83E-05	0
Cs-137	1.61E+02	1.61E+02	0.11	**Pu-237**	3.59E-05	3.16E-06	0
Y-90	1.56E+02	1.56E+02	0.107	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.107	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.012	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.35E+02	1.57E+02	0.107	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.21E+02	8.96E+01	0.061	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	8.53E+01	1.16E+02	0.079	**Am-241**	5.84E-05	4.28E-05	0
Cs-134	7.11E+01	5.25E+01	0.036	**Am-242m**	5.39E-07	5.39E-07	0
Te-132	6.16E+01	7.76E+01	0.053	**Am-242**	5.37E-07	5.48E-07	0
Pr-144m	5.81E+01	4.01E+01	0.027	**Am-243**	2.46E-06	7.67E-07	0
Te-127	4.72E+01	4.72E+01	0.032	**Cm-242**	1.95E-03	3.07E-04	0
Pm-148m	4.57E+01	5.27E+01	0.036	**Cm-243**	2.24E-07	2.85E-07	0
Te-127m	4.21E+01	4.32E+01	0.029	**Cm-244**	5.99E-05	4.03E-06	0
Pm-148	3.78E+01	3.79E+01	0.026				
Mo-99	2.61E+01	2.66E+01	0.018	**Total**	1.38E+05	1.46E+05	100

Table C.1 Day 32 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.65E+04	2.04E+04	14.247	**Mo-99**	2.03E+01	2.07E+01	0.014
Zr-95	1.61E+04	1.62E+04	11.297	**Tc-99m**	1.95E+01	2.15E+00	0.002
Y-91	1.54E+04	1.54E+04	10.744	**Th-231**	2.68E-04	5.71E-04	0
Nb-95	1.33E+04	1.33E+04	9.318	**Th-234**	3.94E-06	3.63E-06	0
Sr-89	1.27E+04	1.27E+04	8.885	**Pa-233**	1.31E-04	2.36E-04	0
La-140	1.05E+04	1.08E+04	7.543	**Pa-234m**	3.95E-06	3.99E-06	0
Pr-143	1.04E+04	1.04E+04	7.235	**U-232**	3.76E-07	1.25E-07	0
Ba-140	9.12E+03	1.08E+04	7.578	**U-234**	5.58E-04	1.55E-04	0
Ru-103	8.50E+03	8.61E+03	6.016	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	7.66E+03	6.91E+03	4.83	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.83E+03	4.83E+03	3.376	**U-237**	3.89E+02	8.70E+02	0.608
Ce-144	4.83E+03	5.61E+03	3.922	**U-238**	4.35E-06	9.97E-07	0
Nd-147	2.52E+03	4.09E+03	2.858	**Np-235**	1.37E-06	4.40E-08	0
Pm-147	4.94E+02	4.94E+02	0.345	**Np-237**	2.20E-04	2.51E-04	0
Rh-106	2.82E+02	2.83E+02	0.198	**Np-238**	2.43E-02	3.73E-02	0
Ru-106	2.82E+02	0.00E+00	0	**Np-239**	1.66E-01	3.87E-01	0
Te-129m	2.03E+02	2.05E+02	0.144	**Pu-236**	8.69E-05	2.83E-05	0
Cs-137	1.61E+02	1.61E+02	0.113	**Pu-237**	3.54E-05	3.12E-06	0
Y-90	1.56E+02	1.56E+02	0.109	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.109	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.012	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.32E+02	1.54E+02	0.107	**Pu-241**	3.34E-01	2.17E-05	0
Nb-95m	1.20E+02	8.87E+01	0.062	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	8.15E+01	1.11E+02	0.078	**Am-241**	5.99E-05	4.39E-05	0
Cs-134	7.11E+01	5.25E+01	0.037	**Am-242m**	5.39E-07	5.39E-07	0
Pr-144m	5.80E+01	4.00E+01	0.028	**Am-242**	5.37E-07	5.48E-07	0
Te-132	4.98E+01	6.27E+01	0.044	**Am-243**	2.46E-06	7.67E-07	0
Te-127	4.59E+01	4.60E+01	0.032	**Cm-242**	1.94E-03	3.05E-04	0
Pm-148m	4.50E+01	5.18E+01	0.036	**Cm-243**	2.24E-07	2.85E-07	0
Te-127m	4.18E+01	4.29E+01	0.03	**Cm-244**	5.99E-05	4.03E-06	0
Pm-148	3.35E+01	3.36E+01	0.023				
Cs-136	2.04E+01	2.68E+01	0.019	**Total**	1.35E+05	1.43E+05	100

Table C.1 Day 33 after irradiation

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-141	1.62E+04	2.00E+04	14.268	**Mo-99**	1.57E+01	1.61E+01	0.011
Zr-95	1.60E+04	1.60E+04	11.429	**Tc-99m**	1.52E+01	1.67E+00	0.001
Y-91	1.52E+04	1.52E+04	10.864	**Th-231**	2.68E-04	5.71E-04	0
Nb-95	1.34E+04	1.34E+04	9.57	**Th-234**	3.96E-06	3.64E-06	0
Sr-89	1.25E+04	1.25E+04	8.969	**Pa-233**	1.33E-04	2.40E-04	0
La-140	9.94E+03	1.02E+04	7.309	**Pa-234m**	3.96E-06	4.00E-06	0
Pr-143	9.84E+03	9.84E+03	7.036	**U-232**	3.78E-07	1.26E-07	0
Ba-140	8.63E+03	1.03E+04	7.345	**U-234**	5.58E-04	1.55E-04	0
Ru-103	8.35E+03	8.46E+03	6.047	**U-235**	2.68E-04	1.33E-04	0
Rh-103m	7.53E+03	6.79E+03	4.856	**U-236**	7.33E-04	1.91E-04	0
Pr-144	4.82E+03	4.82E+03	3.446	**U-237**	3.51E+02	7.85E+02	0.562
Ce-144	4.82E+03	5.60E+03	4.002	**U-238**	4.35E-06	9.97E-07	0
Nd-147	2.37E+03	3.84E+03	2.746	**Np-235**	1.36E-06	4.39E-08	0
Pm-147	4.96E+02	4.96E+02	0.354	**Np-237**	2.20E-04	2.51E-04	0
Rh-106	2.82E+02	2.82E+02	0.202	**Np-238**	1.75E-02	2.69E-02	0
Ru-106	2.82E+02	0.00E+00	0	**Np-239**	1.24E-01	2.88E-01	0
Te-129m	1.99E+02	2.01E+02	0.144	**Pu-236**	8.68E-05	2.83E-05	0
Cs-137	1.61E+02	1.61E+02	0.115	**Pu-237**	3.49E-05	3.07E-06	0
Y-90	1.56E+02	1.56E+02	0.112	**Pu-238**	2.33E-01	4.06E-02	0
Sr-90	1.56E+02	1.56E+02	0.112	**Pu-239**	3.23E-03	2.52E-04	0
Ba-137m	1.53E+02	1.69E+01	0.012	**Pu-240**	1.87E-03	3.09E-04	0
Te-129	1.29E+02	1.51E+02	0.108	**Pu-241**	3.34E-01	2.16E-05	0
Nb-95m	1.18E+02	8.77E+01	0.063	**Pu-242**	9.97E-07	1.37E-07	0
Eu-156	7.79E+01	1.06E+02	0.076	**Am-241**	6.13E-05	4.50E-05	0
Cs-134	7.10E+01	5.24E+01	0.037	**Am-242m**	5.39E-07	5.39E-07	0
Pr-144m	5.78E+01	3.99E+01	0.029	**Am-242**	5.37E-07	5.48E-07	0
Te-127	4.49E+01	4.49E+01	0.032	**Am-243**	2.46E-06	7.67E-07	0
Pm-148m	4.42E+01	5.10E+01	0.036	**Cm-242**	1.94E-03	3.04E-04	0
Te-127m	4.16E+01	4.26E+01	0.03	**Cm-243**	2.24E-07	2.85E-07	0
Te-132	4.02E+01	5.07E+01	0.036	**Cm-244**	5.99E-05	4.03E-06	0
Pm-148	2.97E+01	2.98E+01	0.021				
Cs-136	1.94E+01	2.54E+01	0.018	**Total**	1.32E+05	1.40E+05	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release

Day 1 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Nb-97	2.90E+02	2.91E+02	13.209	**Sb-129**	5.64E+00	5.72E+00	0.26
Zr-97	2.70E+02	2.71E+02	12.295	**Sm-153**	4.91E+00	7.86E+00	0.357
Nb-97m	2.56E+02	5.30E+00	0.241	**Ag-109m**	3.73E+00	3.60E+00	0.164
Y-93	2.53E+02	2.54E+02	11.532	**Pd-109**	3.73E+00	7.33E+00	0.333
Ce-143	2.27E+02	2.74E+02	12.436	**Te-131**	3.64E+00	4.29E+00	0.195
Sr-91	2.21E+02	2.21E+02	10.05	**Rh-105m**	3.21E+00	0.00E+00	0
Mo-99	1.48E+02	1.52E+02	6.886	**Sb-127**	3.00E+00	3.17E+00	0.144
Y-91m	1.40E+02	7.01E+00	0.319	**Te-127**	2.16E+00	2.16E+00	0.098
Tc-99m	1.31E+02	1.45E+01	0.659	**Pr-144**	1.66E+00	1.66E+00	0.075
Y-92	1.03E+02	1.03E+02	4.691	**Ce-144**	1.66E+00	1.93E+00	0.088
Te-132	9.25E+01	1.17E+02	5.3	**Ag-112**	6.86E-01	6.88E-01	0.031
Pr-145	8.72E+01	8.80E+01	4.001	**Pd-112**	5.86E-01	0.00E+00	0
La-141	4.85E+01	4.85E+01	2.204	**Sm-156**	5.56E-01	7.08E-01	0.032
Rh-105	4.06E+01	4.08E+01	1.856	**Sn-121**	5.41E-01	5.41E-01	0.025
Ba-140	3.95E+01	4.70E+01	2.134	**Sb-128**	3.87E-01	4.08E-01	0.019
Pm-149	3.19E+01	3.19E+01	1.452	**Th-231**	9.69E-03	2.06E-02	0.001
Pm-151	1.71E+01	2.12E+01	0.961	**Th-234**	6.20E-06	5.71E-06	0
Nd-147	1.65E+01	2.67E+01	1.213	**Pa-234m**	6.20E-06	6.27E-06	0
Te-131m	1.62E+01	1.92E+01	0.873	**Pa-234**	5.10E-09	1.72E-08	0
Ce-141	1.52E+01	1.87E+01	0.851	**U-234**	6.25E-04	1.74E-04	0
Pr-143	1.44E+01	1.44E+01	0.655	**U-235**	2.02E-02	1.00E-02	0
La-140	1.39E+01	1.43E+01	0.649	**U-236**	6.70E-06	1.75E-06	0
Ru-105	1.14E+01	1.16E+01	0.527	**U-237**	1.16E-02	2.60E-02	0.001
Sr-92	9.78E+00	9.79E+00	0.445	**U-238**	2.19E-04	5.01E-05	0
Zr-95	8.70E+00	8.72E+00	0.396	**U-240**	3.99E-07	5.30E-07	0
Rb-88	8.15E+00	8.15E+00	0.371	**Np-239**	3.65E+00	8.47E+00	0.385
Sr-89	7.96E+00	7.96E+00	0.362	**Np-240m**	4.03E-07	6.26E-07	0
Y-91	6.97E+00	6.97E+00	0.317	**Pu-239**	3.27E-07	2.56E-08	0
Te-129	6.81E+00	7.93E+00	0.36				
Ru-103	6.57E+00	6.66E+00	0.303				
Rh-103m	5.93E+00	5.35E+00	0.243	**Total**	2.59E+03	2.20E+03	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 2 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Ce-143	1.37E+02	1.65E+02	17.198	**Y-92**	1.16E+00	1.16E+00	0.121
Mo-99	1.15E+02	1.18E+02	12.246	**Ag-109m**	1.09E+00	1.05E+00	0.109
Tc-99m	1.10E+02	1.22E+01	1.267	**Pd-109**	1.09E+00	2.13E+00	0.222
Nb-97	1.02E+02	1.02E+02	10.592	**La-141**	7.04E-01	7.04E-01	0.073
Zr-97	1.01E+02	1.01E+02	10.519	**Nb-95**	3.33E-01	3.34E-01	0.035
Nb-97m	9.56E+01	1.98E+00	0.206	**Ag-112**	3.03E-01	3.04E-01	0.032
Te-132	7.48E+01	9.42E+01	9.804	**Sn-121**	2.91E-01	2.91E-01	0.03
Y-93	4.88E+01	4.89E+01	5.085	**Ru-105**	2.69E-01	2.73E-01	0.028
Sr-91	3.83E+01	3.84E+01	3.994	**Te-129**	2.58E-01	3.00E-01	0.031
Ba-140	3.74E+01	4.45E+01	4.627	**Pd-112**	2.56E-01	0.00E+00	0
Rh-105	2.64E+01	2.65E+01	2.756	**In-115m**	2.56E-01	1.40E-01	0.015
Y-91m	2.44E+01	1.22E+00	0.127	**Cd-115**	2.35E-01	2.38E-01	0.025
Pm-149	2.33E+01	2.34E+01	2.429	**As-77**	1.95E-01	1.96E-01	0.02
Pr-143	2.25E+01	2.25E+01	2.345	**Te-129m**	1.76E-01	1.78E-01	0.019
La-140	2.22E+01	2.28E+01	2.372	**Ag-111**	1.69E-01	1.69E-01	0.018
Nd-147	1.55E+01	2.51E+01	2.608	**Th-231**	1.47E-02	3.14E-02	0.003
Ce-141	1.51E+01	1.86E+01	1.938	**Th-234**	1.22E-05	1.13E-05	0
Pm-151	9.52E+00	1.18E+01	1.225	**Pa-231**	1.03E-09	5.61E-10	0
Te-131m	9.28E+00	1.10E+01	1.148	**Pa-234m**	1.22E-05	1.24E-05	0
Zr-95	8.61E+00	8.62E+00	0.897	**Pa-234**	1.28E-08	4.31E-08	0
Y-91	8.18E+00	8.18E+00	0.851	**U-234**	6.25E-04	1.74E-04	0
Sr-89	7.86E+00	7.86E+00	0.817	**U-235**	2.02E-02	1.00E-02	0.001
Ru-103	6.46E+00	6.54E+00	0.68	**U-236**	6.70E-06	1.75E-06	0
Rh-103m	5.82E+00	5.25E+00	0.546	**U-237**	1.05E-02	2.35E-02	0.002
Pr-145	5.40E+00	5.45E+00	0.567	**U-238**	2.19E-04	5.01E-05	0
Sm-153	3.44E+00	5.50E+00	0.572	**U-240**	1.23E-07	1.63E-07	0
Sb-127	2.51E+00	2.65E+00	0.275	**Np-239**	2.72E+00	6.31E+00	0.657
Te-127	2.28E+00	2.28E+00	0.238	**Np-240m**	1.24E-07	1.92E-07	0
Te-131	2.09E+00	2.46E+00	0.256	**Pu-239**	5.76E-07	4.50E-08	0
Pr-144	1.66E+00	1.66E+00	0.172				
Ce-144	1.66E+00	1.92E+00	0.2	**Total**	1.09E+03	9.61E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 3 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Mo-99	8.97E+01	9.15E+01	14.958	**Pr-145**	3.35E-01	3.38E-01	0.055
Tc-99m	8.63E+01	9.53E+00	1.557	**Ag-109m**	3.15E-01	3.04E-01	0.05
Ce-143	8.27E+01	9.98E+01	16.318	**Pd-109**	3.15E-01	6.19E-01	0.101
Te-132	6.04E+01	7.62E+01	12.451	**In-115m**	1.87E-01	1.03E-01	0.017
Nb-97	3.79E+01	3.80E+01	6.21	**Te-129m**	1.73E-01	1.75E-01	0.029
Zr-97	3.77E+01	3.78E+01	6.175	**Cd-115**	1.72E-01	1.74E-01	0.028
Nb-97m	3.57E+01	7.40E-01	0.121	**Sn-121**	1.56E-01	1.56E-01	0.026
Ba-140	3.54E+01	4.21E+01	6.887	**Ag-111**	1.54E-01	1.54E-01	0.025
La-140	2.70E+01	2.77E+01	4.533	**Ag-112**	1.33E-01	1.33E-01	0.022
Pr-143	2.68E+01	2.68E+01	4.376	**As-77**	1.32E-01	1.32E-01	0.022
Pm-149	1.70E+01	1.71E+01	2.79	**Te-129**	1.15E-01	1.34E-01	0.022
Rh-105	1.65E+01	1.66E+01	2.71	**Pd-112**	1.12E-01	0.00E+00	0
Ce-141	1.48E+01	1.82E+01	2.981	**Rh-106**	9.34E-02	9.35E-02	0.015
Nd-147	1.45E+01	2.35E+01	3.848	**Ru-106**	9.34E-02	0.00E+00	0
Y-93	9.40E+00	9.41E+00	1.539	**Th-231**	1.74E-02	3.70E-02	0.006
Zr-95	8.52E+00	8.53E+00	1.394	**Th-234**	1.81E-05	1.66E-05	0
Y-91	8.31E+00	8.31E+00	1.359	**Pa-231**	1.97E-09	1.07E-09	0
Sr-89	7.75E+00	7.75E+00	1.267	**Pa-234m**	1.81E-05	1.83E-05	0
Sr-91	6.66E+00	6.66E+00	1.089	**Pa-234**	2.04E-08	6.91E-08	0
Ru-103	6.35E+00	6.43E+00	1.05	**U-234**	6.25E-04	1.74E-04	0
Rh-103m	5.72E+00	5.16E+00	0.843	**U-235**	2.02E-02	1.00E-02	0.002
Te-131m	5.33E+00	6.34E+00	1.036	**U-236**	6.70E-06	1.75E-06	0
Pm-151	5.30E+00	6.55E+00	1.071	**U-237**	9.46E-03	2.12E-02	0.003
Y-91m	4.23E+00	2.11E-01	0.035	**U-238**	2.19E-04	5.01E-05	0
Sm-153	2.41E+00	3.85E+00	0.63	**U-240**	3.77E-08	5.00E-08	0
Sb-127	2.09E+00	2.21E+00	0.361	**Np-239**	2.03E+00	4.70E+00	0.769
Te-127	1.99E+00	1.99E+00	0.325	**Np-240m**	3.80E-08	5.91E-08	0
Pr-144	1.65E+00	1.65E+00	0.27	**Pu-239**	7.62E-07	5.96E-08	0
Ce-144	1.65E+00	1.92E+00	0.314				
Te-131	1.20E+00	1.42E+00	0.231				
Nb-95	4.93E-01	4.94E-01	0.081	**Total**	6.66E+02	6.12E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 4 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Mo-99	6.97E+01	7.11E+01	15.704	**Nb-95**	6.48E-01	6.49E-01	0.143
Tc-99m	6.71E+01	7.41E+00	1.636	**Te-129m**	1.69E-01	1.71E-01	0.038
Ce-143	5.00E+01	6.03E+01	13.315	**Ag-111**	1.40E-01	1.40E-01	0.031
Te-132	4.89E+01	6.16E+01	13.595	**In-115m**	1.37E-01	7.53E-02	0.017
Ba-140	3.36E+01	3.99E+01	8.813	**Cd-115**	1.26E-01	1.28E-01	0.028
La-140	2.95E+01	3.03E+01	6.695	**Te-129**	1.10E-01	1.28E-01	0.028
Pr-143	2.87E+01	2.87E+01	6.329	**Rh-106**	9.32E-02	9.33E-02	0.021
Ce-141	1.45E+01	1.79E+01	3.944	**Ru-106**	9.32E-02	0.00E+00	0
Nb-97	1.42E+01	1.42E+01	3.136	**Ag-109m**	9.16E-02	8.83E-02	0.019
Zr-97	1.41E+01	1.41E+01	3.118	**Pd-109**	9.16E-02	1.80E-01	0.04
Nd-147	1.36E+01	2.21E+01	4.882	**As-77**	8.70E-02	8.72E-02	0.019
Nb-97m	1.34E+01	2.77E-01	0.061	**Sn-121**	8.41E-02	8.41E-02	0.019
Pm-149	1.24E+01	1.25E+01	2.756	**Sn-125**	7.79E-02	7.76E-02	0.017
Rh-105	1.03E+01	1.04E+01	2.288	**Eu-156**	7.19E-02	9.80E-02	0.022
Zr-95	8.42E+00	8.44E+00	1.863	**Th-231**	1.87E-02	3.99E-02	0.009
Y-91	8.25E+00	8.25E+00	1.822	**Th-234**	2.38E-05	2.19E-05	0
Sr-89	7.64E+00	7.64E+00	1.688	**Pa-231**	3.02E-09	1.64E-09	0
Ru-103	6.24E+00	6.31E+00	1.394	**Pa-234m**	2.38E-05	2.40E-05	0
Rh-103m	5.62E+00	5.07E+00	1.119	**Pa-234**	2.79E-08	9.44E-08	0
Te-131m	3.06E+00	3.64E+00	0.804	**U-234**	6.25E-04	1.74E-04	0
Pm-151	2.95E+00	3.65E+00	0.805	**U-235**	2.02E-02	1.00E-02	0.002
Y-93	1.81E+00	1.81E+00	0.4	**U-236**	6.70E-06	1.75E-06	0
Sb-127	1.75E+00	1.85E+00	0.408	**U-237**	8.54E-03	1.91E-02	0.004
Sm-153	1.69E+00	2.70E+00	0.596	**U-238**	2.19E-04	5.01E-05	0
Te-127	1.68E+00	1.68E+00	0.371	**U-240**	1.16E-08	1.54E-08	0
Pr-144	1.65E+00	1.65E+00	0.364	**Np-239**	1.51E+00	3.51E+00	0.774
Ce-144	1.65E+00	1.91E+00	0.423	**Np-240m**	1.17E-08	1.82E-08	0
Sr-91	1.16E+00	1.16E+00	0.255	**Pu-239**	9.00E-07	7.04E-08	0
Y-91m	7.34E-01	3.67E-02	0.008				
Te-131	6.89E-01	8.13E-01	0.179	**Total**	4.78E+02	4.53E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 5 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Mo-99	5.42E+01	5.53E+01	15.213	**Sr-91**	2.01E-01	2.01E-01	0.055
Tc-99m	5.22E+01	5.76E+00	1.585	**Te-129m**	1.66E-01	1.68E-01	0.046
Te-132	3.95E+01	4.98E+01	13.699	**Ag-111**	1.28E-01	1.28E-01	0.035
Ba-140	3.18E+01	3.78E+01	10.404	**Y-91m**	1.27E-01	6.36E-03	0.002
La-140	3.05E+01	3.14E+01	8.646	**Te-129**	1.08E-01	1.26E-01	0.035
Ce-143	3.02E+01	3.64E+01	10.025	**In-115m**	1.01E-01	5.52E-02	0.015
Pr-143	2.92E+01	2.92E+01	8.032	**Rh-106**	9.30E-02	9.32E-02	0.026
Ce-141	1.42E+01	1.75E+01	4.811	**Ru-106**	9.30E-02	0.00E+00	0
Nd-147	1.28E+01	2.08E+01	5.717	**Cd-115**	9.25E-02	9.34E-02	0.026
Pm-149	9.09E+00	9.12E+00	2.51	**Sn-125**	7.25E-02	7.22E-02	0.02
Zr-95	8.33E+00	8.35E+00	2.297	**Eu-156**	6.88E-02	9.37E-02	0.026
Y-91	8.16E+00	8.16E+00	2.246	**As-77**	5.69E-02	5.70E-02	0.016
Sr-89	7.54E+00	7.54E+00	2.075	**Pm-147**	5.41E-02	5.41E-02	0.015
Rh-105	6.44E+00	6.47E+00	1.781	**Th-231**	1.94E-02	4.14E-02	0.011
Ru-103	6.13E+00	6.20E+00	1.707	**Th-234**	2.93E-05	2.70E-05	0
Rh-103m	5.52E+00	4.98E+00	1.371	**Pa-231**	4.13E-09	2.24E-09	0
Nb-97	5.29E+00	5.31E+00	1.46	**Pa-234m**	2.93E-05	2.96E-05	0
Zr-97	5.27E+00	5.28E+00	1.452	**Pa-234**	3.52E-08	1.19E-07	0
Nb-97m	4.99E+00	1.03E-01	0.028	**U-234**	6.25E-04	1.74E-04	0
Te-131m	1.76E+00	2.09E+00	0.575	**U-235**	2.02E-02	1.00E-02	0.003
Pr-144	1.64E+00	1.64E+00	0.453	**U-236**	6.70E-06	1.75E-06	0
Ce-144	1.64E+00	1.91E+00	0.525	**U-237**	7.71E-03	1.72E-02	0.005
Pm-151	1.64E+00	2.03E+00	0.558	**U-238**	2.19E-04	5.01E-05	0
Sb-127	1.46E+00	1.54E+00	0.424	**U-240**	3.56E-09	4.73E-09	0
Te-127	1.41E+00	1.41E+00	0.388	**Np-239**	1.12E+00	2.61E+00	0.719
Sm-153	1.18E+00	1.89E+00	0.52	**Np-240m**	3.59E-09	5.58E-09	0
Nb-95	7.99E-01	8.00E-01	0.22	**Pu-239**	1.00E-06	7.84E-08	0
Te-131	3.96E-01	4.67E-01	0.128				
Y-93	3.49E-01	3.49E-01	0.096	**Total**	3.76E+02	3.63E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 6 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Mo-99	4.21E+01	4.30E+01	14.046	**Te-129**	1.06E-01	1.23E-01	0.04
Tc-99m	4.06E+01	4.48E+00	1.463	**Rh-106**	9.28E-02	9.30E-02	0.03
Te-132	3.19E+01	4.02E+01	13.153	**Ru-106**	9.28E-02	0.00E+00	0
La-140	3.07E+01	3.15E+01	10.305	**In-115m**	7.37E-02	4.04E-02	0.013
Ba-140	3.01E+01	3.58E+01	11.708	**Cd-115**	6.78E-02	6.84E-02	0.022
Pr-143	2.89E+01	2.89E+01	9.452	**Sn-125**	6.74E-02	6.72E-02	0.022
Ce-143	1.82E+01	2.20E+01	7.193	**Y-93**	6.72E-02	6.73E-02	0.022
Ce-141	1.39E+01	1.71E+01	5.594	**Eu-156**	6.57E-02	8.96E-02	0.029
Nd-147	1.20E+01	1.95E+01	6.379	**Pm-147**	6.31E-02	6.31E-02	0.021
Zr-95	8.24E+00	8.26E+00	2.699	**Cs-137**	4.90E-02	4.90E-02	0.016
Y-91	8.07E+00	8.07E+00	2.637	**Sr-90**	4.87E-02	4.87E-02	0.016
Sr-89	7.44E+00	7.44E+00	2.431	**Ba-137m**	4.63E-02	5.12E-03	0.002
Pm-149	6.65E+00	6.67E+00	2.179	**Th-230**	9.25E-11	2.15E-11	0
Ru-103	6.02E+00	6.09E+00	1.992	**Th-231**	1.98E-02	4.22E-02	0.014
Rh-103m	5.43E+00	4.89E+00	1.6	**Th-234**	3.47E-05	3.19E-05	0
Rh-105	4.02E+00	4.04E+00	1.322	**Pa-231**	5.27E-09	2.86E-09	0
Nb-97	1.98E+00	1.98E+00	0.648	**Pa-234m**	3.47E-05	3.50E-05	0
Zr-97	1.97E+00	1.97E+00	0.644	**Pa-234**	4.22E-08	1.43E-07	0
Nb-97m	1.87E+00	3.86E-02	0.013	**U-234**	6.25E-04	1.74E-04	0
Pr-144	1.64E+00	1.64E+00	0.536	**U-235**	2.02E-02	1.00E-02	0.003
Ce-144	1.64E+00	1.90E+00	0.623	**U-236**	6.70E-06	1.75E-06	0
Sb-127	1.22E+00	1.29E+00	0.421	**U-237**	6.95E-03	1.56E-02	0.005
Te-127	1.18E+00	1.18E+00	0.385	**U-238**	2.19E-04	5.01E-05	0
Te-131m	1.01E+00	1.20E+00	0.393	**U-240**	1.09E-09	1.45E-09	0
Nb-95	9.45E-01	9.46E-01	0.309	**Np-239**	8.37E-01	1.95E+00	0.636
Pm-151	9.13E-01	1.13E+00	0.369	**Np-240m**	1.10E-09	1.72E-09	0
Sm-153	8.28E-01	1.32E+00	0.433	**Pu-239**	1.08E-06	8.44E-08	0
Te-131	2.27E-01	2.68E-01	0.088				
Te-129m	1.62E-01	1.64E-01	0.054				
Ag-111	1.16E-01	1.17E-01	0.038	**Total**	3.12E+02	3.06E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 7 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
Mo-99	3.27E+01	3.34E+01	12.572	**Te-129**	1.04E-01	1.20E-01	0.045
Tc-99m	3.15E+01	3.48E+00	1.31	**Rh-106**	9.27E-02	9.28E-02	0.035
La-140	3.02E+01	3.10E+01	11.683	**Ru-106**	9.27E-02	0.00E+00	0
Ba-140	2.85E+01	3.39E+01	12.771	**Pm-147**	7.14E-02	7.14E-02	0.027
Pr-143	2.82E+01	2.82E+01	10.61	**Eu-156**	6.28E-02	8.56E-02	0.032
Te-132	2.58E+01	3.25E+01	12.244	**Sn-125**	6.28E-02	6.26E-02	0.024
Ce-141	1.36E+01	1.68E+01	6.307	**In-115m**	5.40E-02	2.96E-02	0.011
Nd-147	1.13E+01	1.83E+01	6.898	**Cd-115**	4.97E-02	5.01E-02	0.019
Ce-143	1.10E+01	1.33E+01	5.004	**Cs-137**	4.90E-02	4.90E-02	0.018
Zr-95	8.16E+00	8.17E+00	3.075	**Sr-90**	4.87E-02	4.87E-02	0.018
Y-91	7.97E+00	7.97E+00	3.002	**Ba-137m**	4.63E-02	5.12E-03	0.002
Sr-89	7.34E+00	7.34E+00	2.762	**Nb-95m**	4.36E-02	3.23E-02	0.012
Ru-103	5.91E+00	5.99E+00	2.254	**Y-90**	4.08E-02	4.09E-02	0.015
Rh-103m	5.33E+00	4.81E+00	1.81	**Th-230**	1.08E-10	2.51E-11	0
Pm-149	4.86E+00	4.87E+00	1.834	**Th-231**	2.00E-02	4.26E-02	0.016
Rh-105	2.51E+00	2.53E+00	0.951	**Th-234**	3.99E-05	3.67E-05	0
Pr-144	1.64E+00	1.64E+00	0.616	**Pa-231**	6.42E-09	3.48E-09	0
Ce-144	1.64E+00	1.90E+00	0.715	**Pa-234m**	3.99E-05	4.03E-05	0
Nb-95	1.09E+00	1.09E+00	0.41	**Pa-234**	4.91E-08	1.66E-07	0
Sb-127	1.02E+00	1.08E+00	0.405	**U-234**	6.25E-04	1.74E-04	0
Te-127	9.86E-01	9.87E-01	0.372	**U-235**	2.02E-02	1.00E-02	0.004
Nb-97	7.39E-01	7.41E-01	0.279	**U-236**	6.70E-06	1.75E-06	0
Zr-97	7.36E-01	7.37E-01	0.277	**U-237**	6.28E-03	1.40E-02	0.005
Nb-97m	6.97E-01	1.44E-02	0.005	**U-238**	2.19E-04	5.01E-05	0
Te-131m	5.80E-01	6.90E-01	0.26	**U-240**	3.36E-10	4.46E-10	0
Sm-153	5.80E-01	9.27E-01	0.349	**Np-239**	6.24E-01	1.45E+00	0.546
Pm-151	5.08E-01	6.29E-01	0.237	**Np-240m**	3.39E-10	5.27E-10	0
Te-129m	1.59E-01	1.61E-01	0.061	**Pu-239**	1.14E-06	8.89E-08	0
Te-131	1.31E-01	1.54E-01	0.058				
Ag-111	1.06E-01	1.06E-01	0.04	**Total**	2.67E+02	2.66E+02	100

Table C.2 Activity (Ci) of solid radionuclides produced in the criticality event of October 16, 1959, and fractional contribution to (ß-I) aerosol release - continued

Day 8 After the criticality event

Nuclide	Activity Ci	Effective Activity Ci	Contribution %	Nuclide	Activity Ci	Effective Activity Ci	Contribution %
La-140	2.93E+01	3.02E+01	12.805	**Ru-106**	9.25E-02	0.00E+00	0
Pr-143	2.72E+01	2.72E+01	11.549	**Pm-147**	7.93E-02	7.93E-02	0.034
Ba-140	2.70E+01	3.21E+01	13.637	**Te-131**	7.50E-02	8.85E-02	0.038
Mo-99	2.54E+01	2.60E+01	11.014	**Eu-156**	6.00E-02	8.18E-02	0.035
Tc-99m	2.45E+01	2.70E+00	1.147	**Sn-125**	5.84E-02	5.82E-02	0.025
Te-132	2.09E+01	2.63E+01	11.158	**Cs-137**	4.90E-02	4.90E-02	0.021
Ce-141	1.33E+01	1.64E+01	6.961	**Sr-90**	4.87E-02	4.87E-02	0.021
Nd-147	1.06E+01	1.72E+01	7.304	**Ba-137m**	4.63E-02	5.12E-03	0.002
Zr-95	8.07E+00	8.08E+00	3.428	**Nb-95m**	4.59E-02	3.40E-02	0.014
Y-91	7.88E+00	7.88E+00	3.344	**Y-90**	4.26E-02	4.26E-02	0.018
Sr-89	7.24E+00	7.24E+00	3.071	**In-115m**	3.96E-02	2.17E-02	0.009
Ce-143	6.65E+00	8.03E+00	3.407	**Cd-115**	3.64E-02	3.67E-02	0.016
Ru-103	5.81E+00	5.88E+00	2.497	**Th-230**	1.23E-10	2.86E-11	0
Rh-103m	5.24E+00	4.72E+00	2.005	**Th-231**	2.01E-02	4.28E-02	0.018
Pm-149	3.55E+00	3.56E+00	1.512	**Th-234**	4.49E-05	4.14E-05	0
Pr-144	1.63E+00	1.63E+00	0.693	**Pa-231**	7.58E-09	4.11E-09	0
Ce-144	1.63E+00	1.90E+00	0.804	**Pa-234m**	4.49E-05	4.54E-05	0
Rh-105	1.57E+00	1.58E+00	0.669	**Pa-234**	5.57E-08	1.89E-07	0
Nb-95	1.22E+00	1.23E+00	0.52	**U-234**	6.25E-04	1.74E-04	0
Sb-127	8.50E-01	8.98E-01	0.381	**U-235**	2.02E-02	1.00E-02	0.004
Te-127	8.27E-01	8.27E-01	0.351	**U-236**	6.70E-06	1.75E-06	0
Sm-153	4.06E-01	6.49E-01	0.275	**U-237**	5.66E-03	1.27E-02	0.005
Te-131m	3.33E-01	3.96E-01	0.168	**U-238**	2.19E-04	5.01E-05	0
Pm-151	2.83E-01	3.50E-01	0.148	**U-240**	1.03E-10	1.37E-10	0
Nb-97	2.76E-01	2.77E-01	0.117	**Np-237**	6.23E-11	7.10E-11	0
Zr-97	2.75E-01	2.75E-01	0.117	**Np-239**	4.65E-01	1.08E+00	0.458
Nb-97m	2.60E-01	5.40E-03	0.002	**Np-240m**	1.04E-10	1.62E-10	0
Te-129m	1.56E-01	1.58E-01	0.067	**Pu-239**	1.18E-06	9.22E-08	0
Te-129	1.01E-01	1.18E-01	0.05				
Ag-111	9.64E-02	9.67E-02	0.041				
Rh-106	9.25E-02	9.26E-02	0.039	**Total**	2.34E+02	2.36E+02	100

APPENDIX D

EFFECT OF ELECTRON-EMITTING NUCLIDES AND LOW ENERGY BETA-EMITTERS ON THE BETA-MINUS IODINE READING

APPENDIX D: EFFECT OF ELECTRON-EMITTING NUCLIDES AND LOW ENERGY BETA-EMITTERS ON THE BETA-MINUS IODINE READING

Beta-detectors may count both betas emitted by β-decay of the nucleus and so-called Auger and internal conversion electrons, provided they are sufficiently energetic to pass through the detector window.

The first edition of Price (1958), Nuclear Radiation Detection, provides a description of contemporary radiation detection technology. Price states that 30 mg/cm^2 was the common thickness of commercial, thin-walled glass tubes designed for β-counting. This rather hefty thickness can only be penetrated by relatively high-energy betas of about 150 keV (ICRU Report 56, 1997).

Price also states that special, thin window tubes were commercially available for counting soft s with windows at thin as 1.4 mg/cm^2. At that time, the thin windows were made either of Mylar, mica, or stainless steel. Assuming Mylar, for which data are available in ICRU Report 56, will result in a cutoff energy of 25 keV (ICRU Report 56, 1997). Consequently, it is assumed that betas or electrons of less than 25 keV would not have been counted by the β-detectors in use at the ICPP in 1957-1959. This is the assumption used for the determination of the values in the EFFECTIVE ACTIVITY column of Appendix C.

The metastable transition to the ground state may result in the emission of an orbital electron from the inner, K shell. Secondary electrons may also be emitted as a final result of the shifting of the orbital electrons to fill the vacancy in the K-shell. Some fraction of these electrons may be counted by the β-counters in use at the ICPP in 1957-1959 and thus contribute to the (β-I) reading in the stack monitor.

Some nuclides may emit sufficiently low energy betas at least a fraction of the time such that only a fraction of their disintegrations are counted by the 1957-1959 vintage β-detectors. The fraction of electron-emitting metastable nuclides and low energy β-emitters that would not have been counted by the 1957-1959 β-detectors may be determined by comparing the β-energy spectra per disintegration for each nuclide (Eckerman, 1993) with the cutoff energy of 25 keV of the detector. The cutoff energy is the β-energy below which penetration through the detector window does not occur.

Note that some values of EFFECTIVE ACTIVITY in the Appendix C tables are higher than the listed ACTIVITY value. This occurs when, on the average, more than one β plus electron greater than 25 keV is emitted per disintegration.

The Appendix C tables show overwhelmingly that betas emitted by β-decay are predominantly more energetic than 25 keV, and thus would have penetrated the 1.4 mg/cm^2 window and be counted. Thus generally, the values of ACTIVITY and EFFECTIVE ACTIVITY are usually very close, with a few exceptions.