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**Program BIFTOX**  
**A Tool to Calculate the**  
**Radiotoxicity of a Nuclide Mixture**

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## Abstract

A program named BIFTOX is described, which can be used to calculate the radiotoxicity of actinides and fission products in spent fuel as a function of the storage time up to one million years. It uses the most recent dose coefficients from the ICRP publication 68.

Also a comparison between these dose coefficients and the old ones from ICRP publication 61 is given.

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# 1. INTRODUCTION

The radiotoxicity of actinides and fission products in nuclear waste is an important parameter for the assessment of nuclear fuel cycle scenarios. Usually, this parameter is calculated by means of dose coefficients, which give the relation between the activity of a nuclide and the dose upon ingestion or inhalation of that nuclide. Its units are Annual Limit on Intake (ALI) for the dose coefficients of reference [1] and Sv/Bq for the more recent dose coefficients of reference [2]. These two units can be converted to each other, knowing that one ALI is by definition that amount of a nuclide in units of Bq giving a dose of 0.02 Sv:

$$ALI = \frac{0.02}{e(50)} \quad (1.1)$$

where  $e(50)$  is the dose coefficient in units of Sv/Bq calculated over 50 years [2].

At the Netherlands Energy Research Foundation (ECN), the undocumented ORITOX program is used to calculate the radiotoxicity of a nuclide mixture calculated by ORIGEN-S [3] based upon the dose coefficients for ingestion of reference [1]. There were two reasons to update this program:

- First, the OCTOPUS burnup and criticality system [4] (also [5]) has been developed, which uses ORIGEN-S for burnup calculations or the FISPACT burnup code. In the first case, ORIGEN-S binary nuclide files are produced which can be read by ORITOX to calculate the radiotoxicity of the nuclide inventory. In the second case, when FISPACT is used for the burnup calculations, only Binary Interface Files (BIF) in OCTOPUS format are produced, and ORITOX cannot be used to calculate the radiotoxicity.
- Secondly, the ICRP has updated the dose coefficients and changed the units from ALI to Sv/Bq which required changes in the code ORITOX anyway.

These two reasons led to the development of the BIFTOX program, which can read nuclide inventories from ORIGEN-S binary nuclide files or from Binary Interface Files (BIF) produced by OCTOPUS. Furthermore, the BIFTOX program uses the dose coefficients for ingestion from reference [2].

This report describes the input for the BIFTOX program, and gives a comparison between the dose coefficients from references [1] and [2].

## 2. INPUT DESCRIPTION

The BIFTOX program can be run by providing the input parameters on the command line or by typing the parameters in an interactive way. Table 2.1 gives the input parameters needed when BIFTOX is to read the nuclide densities from BIF files produced by OCTOPUS, and table 2.2 gives the same when BIFTOX is to read the nuclide densities from a binary nuclide file produced by ORIGEN-S. Note that these two files, when produced by the OCTOPUS system, contain the nuclide densities per unit volume ( $\text{cm}^{-3}$ ) of the fuel. The radiotoxicity is therefore calculated in units of  $\text{Sv cm}^{-3}$ .

Table 2.1 *Input parameters when BIFTOX is used to read nuclide densities from BIF files.*

Parameter	Explanation
IBO	(1) Read nuclide densities from BIF files.
IZONE	Zone number in the BIF files.
IOPT	(1) Treat the nuclide densities read in the file as mother nuclides and calculate the radiotoxicity of these nuclides and daughter products. (2) Read the nuclide densities at all time steps in the BIF files and calculate the radiotoxicity of these nuclide at all steps.
ISTP	Time step for reading the nuclide densities. Only if IOPT is 1.
ISEL	Nuclide selector. Only if IOPT is 2. Calculate the radiotoxicity of (1) actinides, (2) fission products, (3) actinides and fission products, (4) light elements, (5) fission products and light elements or (6) actinides and fission products and light elements.
CUTOFF	(%) Cutoff limit for printing. If the contribution of a nuclide is less than cutoff, the radiotoxicity is not printed. It is however included in the total radiotoxicity (identifier 999999).

Table 2.2 *Input parameter when BIFTOX is used to read nuclide densities from ORIGEN-S binary nuclide files.*

Parameter	Explanation
IBO	(2) Read nuclide densities from ORIGEN-S binary nuclide files.
FILE	Filename of the ORIGEN-S binary nuclide file.
IOPT	(1) Treat the nuclide densities read in the file as mother nuclides and calculate the radiotoxicity of these nuclides and daughter products. (2) Read the nuclide densities at all time steps in the BIF files and calculate the radiotoxicity of these nuclide at all steps.
ISTP	Time step for reading the nuclide densities. Only if IOPT is 1.
ISEL	Nuclide selector. Only if IOPT is 2. Calculate the radiotoxicity of (1) actinides, (2) fission products, (3) actinides and fission products, (4) light elements, (5) fission products and light elements or (6) actinides and fission products and light elements.
CUTOFF	(%) Cutoff limit for printing. If the contribution of a nuclide is less than cutoff, the radiotoxicity is not printed. It is however included in the total radiotoxicity (identifier 999999).

An example of how to use BIFTOX is given below. If an OCTOPUS run is done with 14 burnup time intervals, an ORIGEN-S binary nuclide file is produced with 15 times steps: one at BOL (the fresh fuel composition) and 14 steps at the end of each burnup time interval. Also BIF files are produced: one at BOL (BIF.0), 14 at the end of each burnup time interval (BIF.1 till BIF.14), and one which can be used to restart OCTOPUS (BIF.15). This last BIF file is not needed by the BIFTOX program. The nuclide densities in the files BIF.0 till BIF.14 correspond with the nuclide densities in the ORIGEN-S binary nuclide file steps 1 till 15. If the radiotoxicity due to all actinides in the spent fuel is to be calculated, BIFTOX can be used as follows:

```
BIFTOX 1 1 1 15 1.0
```

which means that BIFTOX reads the nuclide densities from zone number one in BIF.14 (step 15) and calculates the radiotoxicities due to the actinides and all the daughter products at 20 decay time steps at 0, 1, 2, 5, 10, 20, 50, 100, 200, 500,  $1 \cdot 10^3$ ,  $2 \cdot 10^3$ ,  $5 \cdot 10^3$ ,  $1 \cdot 10^4$ ,  $2 \cdot 10^4$ ,  $5 \cdot 10^4$ ,  $1 \cdot 10^5$ ,  $2 \cdot 10^5$ ,  $5 \cdot 10^5$  and  $1 \cdot 10^6$  years of storage.

If ORIGEN-S is used in the OCTOPUS sequence, a file named ORIGEN.1.DEN.15 is produced which contains the nuclide densities in mole  $\text{cm}^{-3}$  and which can also be used by BIFTOX in the following way:

```
BIFTOX 2 ORIGEN.1.DEN.15 1 15 1.0
```

In both cases, only the nuclides with contributions greater than one percent are printed in the output. Besides the contributions of the isotopes of an element, also the total contribution of each element is calculated and printed. The identifier of this contribution is  $Z * 10000$  where  $Z$  is the atomic number of the element.

If the name BIFTOX is typed without input parameters, the input can be given interactively. The next time BIFTOX is run, each input parameter has a default value which equals the value used in the previous BIFTOX run. These default values are stored in the file named 'BIFTOX.SYS'

### 3. RADIOTOXICITY OF NUCLIDES AND DAUGHTERS

As mentioned in chapter 1, the dose coefficients of the two references [1] and [2] can be compared to each other when the unit of ALI is converted to Sv. The dose coefficients of reference [2], and the ratio of this coefficient and that of reference [1] are shown in Appendix A for all common nuclides of the two ICRP publications. The changes for many nuclides are several tens of percents, which will most probably not have a large impact on the results obtained till now by the ORITOX program, which uses dose coefficients of reference [1]. Of the actinides, uranium has become more toxic according to reference [2] (about 70%), while in general plutonium and the minor actinides have become two or three times less toxic. The toxicity of  $^{237}\text{Np}$  is reduced even by a factor of six.

As can be seen in chapter 2, the BIFTOX program has the capability to calculate the radiotoxicity of a 'mother nuclide' and all daughter products. This is done by a table which gives the radiotoxicity of the nuclide mixture when one mole of a nuclide is subject to decay up to  $1 \cdot 10^6$  years. These nuclide mixtures have been calculated by the ORIGEN-S code using a library based on the JEF2.2 evaluated nuclear data file [6]. This procedure is the same as explained in chapter 5 of reference [7] of which the results are given in tables 4.3 till 4.7 in reference [8]. In Appendix B these coefficients are given based on reference [2], and in Appendix C the differences between the radiotoxicity curves of references [2] and [1] are visualized for the most important actinides. In general, the radiotoxicity of most actinides and daughter products is reduced when changing from reference [1] to [2].

## 4. CONCLUSIONS

A program named BIFTOX is made, which can be used to calculate the radiotoxicity of actinides and fission products in spent fuel as a function of the storage time up to one million years. It uses the most recent dose coefficients from reference [2]. Because BIFTOX can read the nuclide densities from Binary Interface Files (BIF) produced by OCTOPUS, and from ORIGEN-S binary nuclide files, it is more general than the undocumented ORITOX program which was used up to now to calculate the radiotoxicity based on ALI values of reference [1].

The differences between the old dose coefficients from the ICRP-61 publication [1] and from the more recent ICRP-68 publication [2] are shown and visualized in Appendix C for the most important actinides. In general, the radiotoxicity of most actinides and the daughter nuclides are less toxic according to the new dose coefficients.

## REFERENCES

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## APPENDIX A. DOSE COEFFICIENTS OF NUCLIDES

Table A.1 *Dose coefficients of nuclides from reference [2] (Sv/Bq) and the ratio of these with those of reference [1].*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
10030	4.2E-11	2.10	240510	3.8E-11	0.76
40070	2.8E-11	0.84	250510	9.3E-11	0.93
40100	1.1E-09	0.55	250520	1.8E-09	0.90
60110	2.4E-11	7.20	250521	6.9E-11	1.04
60140	5.8E-10	1.16	250530	3.0E-11	0.90
90180	4.9E-11	0.98	250540	7.1E-10	1.06
110220	3.2E-09	1.12	250560	2.5E-10	1.13
110240	4.3E-10	1.08	260520	1.4E-09	0.70
120280	2.2E-09	0.88	260550	3.3E-10	1.65
130260	3.5E-09	0.70	260590	1.8E-09	0.90
140310	1.6E-10	1.60	260600	1.1E-07	2.75
140320	5.6E-10	0.56	270550	1.1E-09	1.10
150320	2.4E-09	0.96	270560	2.5E-09	0.75
150330	2.4E-10	0.96	270570	2.1E-10	0.63
160350	7.7E-10	2.69	270580	7.4E-10	0.74
170360	9.3E-10	0.93	270581	2.4E-11	0.96
170380	1.2E-10	1.20	270600	3.4E-09	0.51
170390	8.5E-11	0.85	270601	1.7E-12	0.85
190400	6.2E-09	1.24	270610	7.4E-11	1.11
190420	4.3E-10	1.08	270621	4.7E-11	0.94
190430	2.5E-10	1.13	280560	8.6E-10	0.86
190440	8.4E-11	0.84	280570	8.7E-10	0.87
190450	5.4E-11	1.08	280590	6.3E-11	0.94
200410	2.9E-10	1.01	280630	1.5E-10	0.75
200450	7.6E-10	0.76	280650	1.8E-10	0.90
200470	1.6E-09	0.80	280660	3.0E-09	0.75
210430	1.9E-10	0.95	290600	7.0E-11	1.05
210440	3.5E-10	1.05	290610	1.2E-10	1.20
210441	2.4E-09	0.72	290640	1.2E-10	1.20
210460	1.5E-09	0.75	290670	3.4E-10	0.85
210470	5.4E-10	0.81	300620	9.4E-10	0.94
210480	1.7E-09	0.85	300630	7.9E-11	1.19
210490	8.2E-11	1.23	300650	3.9E-09	0.97
220440	5.8E-09	0.87	300690	3.1E-11	1.09
220450	1.5E-10	0.75	300691	3.3E-10	0.82
230470	6.3E-11	0.94	300711	2.4E-10	1.08
230480	2.0E-09	0.80	300720	1.4E-09	0.70
230490	1.8E-11	0.81	310650	3.7E-11	1.11
240480	2.0E-10	0.80	310660	1.2E-09	1.20
240490	6.1E-11	1.22	310670	1.9E-10	0.76

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
310680	1.0E-10	1.00	370810	5.4E-11	1.08
310700	3.1E-11	1.09	370811	9.7E-12	0.97
310720	1.1E-09	1.10	370821	1.3E-10	1.30
310730	2.6E-10	1.04	370830	1.9E-09	0.95
320660	1.0E-10	1.50	370840	2.8E-09	1.12
320670	6.5E-11	0.98	370860	2.8E-09	1.12
320680	1.3E-09	4.55	370870	1.5E-09	1.50
320690	2.4E-10	2.40	370880	9.0E-11	0.90
320710	1.2E-11	4.80	370890	4.7E-11	0.94
320750	4.6E-11	1.15	380800	3.5E-10	1.23
320770	3.3E-10	1.65	380810	7.8E-11	1.17
320780	1.2E-10	1.20	380820	6.1E-09	0.61
330690	5.7E-11	1.14	380830	5.8E-10	0.87
330700	1.3E-10	1.30	380850	5.6E-10	1.12
330710	4.6E-10	0.92	380851	6.1E-12	1.22
330720	1.8E-09	0.90	380871	3.3E-11	1.15
330730	2.6E-10	1.04	380890	2.6E-09	0.78
330740	1.3E-09	1.30	380900	2.8E-08	0.84
330760	1.6E-09	0.80	380910	7.6E-10	1.14
330770	4.0E-10	1.00	380920	4.9E-10	0.98
330780	2.1E-10	1.05	390860	9.6E-10	0.96
340700	1.4E-10	1.40	390861	5.6E-11	0.84
340730	3.9E-10	0.98	390870	5.5E-10	0.82
340731	4.1E-11	1.02	390880	1.3E-09	0.65
340750	2.6E-09	1.17	390900	2.7E-09	0.68
340790	2.9E-09	1.45	390901	1.7E-10	0.77
340810	2.7E-11	1.08	390910	2.4E-09	0.60
340811	5.9E-11	1.18	390911	1.1E-11	1.10
340830	5.1E-11	1.02	390920	4.9E-10	0.98
350740	8.4E-11	0.84	390930	1.2E-09	1.20
350741	1.4E-10	0.70	390940	8.1E-11	1.22
350750	7.9E-11	1.19	390950	4.6E-11	0.92
350760	4.6E-10	1.15	400860	8.6E-10	0.86
350770	9.6E-11	0.96	400880	3.3E-10	0.82
350800	3.1E-11	1.09	400890	7.9E-10	0.79
350801	1.1E-10	1.10	400930	2.8E-10	0.98
350820	5.4E-10	1.08	400950	8.8E-10	0.88
350830	4.3E-11	1.07	400970	2.1E-09	0.84
350840	8.8E-11	0.88	410880	6.3E-11	1.58
370790	5.0E-11	1.00	410890	3.0E-10	1.20

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
410891	1.4E-10	1.40	451031	3.8E-12	1.14
410900	1.2E-09	0.60	451050	3.7E-10	0.74
410931	1.2E-10	0.60	451061	1.6E-10	0.80
410940	1.7E-09	0.77	451070	2.4E-11	1.08
410950	5.8E-10	0.87	461000	9.4E-10	0.94
410951	5.6E-10	0.56	461010	9.4E-11	0.94
410960	1.1E-09	1.10	461030	1.9E-10	0.67
410970	6.8E-11	1.36	461070	3.7E-11	0.56
410980	1.1E-10	1.10	461090	5.5E-10	0.82
420900	6.2E-10	0.93	471020	4.0E-11	1.00
420930	2.6E-09	10.40	471030	4.3E-11	1.07
420931	2.8E-10	0.98	471040	6.0E-11	1.20
420990	1.2E-09	0.60	471041	5.4E-11	1.08
430930	4.9E-11	1.23	471050	4.7E-10	0.94
430931	2.4E-11	1.08	471060	3.2E-11	1.12
430940	1.8E-10	0.90	471061	1.5E-09	0.75
430941	1.1E-10	1.10	471081	2.3E-09	1.15
430950	1.6E-10	0.80	471101	2.8E-09	0.98
430951	6.2E-10	1.24	471110	1.3E-09	0.65
430960	1.1E-09	1.10	471120	4.3E-10	1.08
430961	1.3E-11	1.30	471150	6.0E-11	0.90
430970	8.3E-11	1.25	481040	5.8E-11	1.16
430971	6.6E-10	1.32	481070	6.2E-11	0.93
430980	2.3E-09	1.15	481090	2.0E-09	0.90
430990	7.8E-10	1.17	481130	2.5E-08	1.00
430991	2.2E-11	1.10	481131	2.3E-08	1.04
431010	1.9E-11	0.95	481150	1.4E-09	0.70
431040	8.1E-11	1.22	481151	3.3E-09	0.82
440940	9.4E-11	1.41	481170	2.8E-10	1.12
440970	1.5E-10	0.75	481171	2.8E-10	0.98
441030	7.3E-10	0.73	491090	6.6E-11	0.99
441050	2.6E-10	0.91	491100	1.0E-10	1.00
441060	7.0E-09	0.70	491101	2.4E-10	1.08
450990	5.1E-10	0.76	491110	2.9E-10	0.73
450991	6.6E-11	0.99	491120	1.0E-11	1.00
451000	7.1E-10	1.06	491131	2.8E-11	1.26
451010	5.5E-10	0.82	491141	4.1E-09	0.62
451011	2.2E-10	0.77	491150	3.2E-08	0.96
451020	2.6E-09	0.91	491151	8.6E-11	0.86
451021	1.2E-09	0.60	491161	6.4E-11	1.28

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
491170	3.1E-11	1.09	521231	1.4E-09	1.40
491171	1.2E-10	1.20	521251	8.7E-10	0.87
491191	4.7E-11	0.94	521270	1.7E-10	0.85
501100	3.5E-10	1.05	521271	2.3E-09	1.04
501110	2.3E-11	1.04	521290	6.3E-11	1.26
501130	7.3E-10	0.73	521291	3.0E-09	0.75
501171	7.1E-10	0.71	521310	8.7E-11	0.26
501191	3.4E-10	0.68	521311	1.9E-09	0.57
501210	2.3E-10	0.81	521320	3.7E-09	0.93
501211	3.8E-10	0.57	521330	7.2E-11	1.08
501230	2.1E-09	0.63	521331	2.8E-10	0.98
501231	3.8E-11	1.14	521340	1.1E-10	1.10
501250	3.1E-09	0.62	531200	3.4E-10	1.02
501260	4.7E-09	0.71	531201	2.1E-10	0.94
501270	2.0E-10	1.00	531210	8.2E-11	0.82
501280	1.5E-10	1.50	531230	2.1E-10	0.94
511150	2.4E-11	1.08	531240	1.3E-08	0.65
511160	2.6E-11	1.04	531250	1.5E-08	0.75
511161	6.7E-11	1.01	531260	2.9E-08	0.87
511170	1.8E-11	0.90	531280	4.6E-11	0.92
511181	2.1E-10	0.94	531290	1.1E-07	1.10
511190	8.1E-11	0.81	531300	2.0E-09	1.00
511201	1.2E-09	0.60	531310	2.2E-08	0.88
511200	1.4E-11	0.70	531320	2.9E-10	1.01
511220	1.7E-09	0.68	531321	2.2E-10	0.99
511240	2.5E-09	0.75	531330	4.3E-09	0.86
511241	8.0E-12	1.20	531340	1.1E-10	1.10
511250	1.1E-09	1.10	531350	9.3E-10	0.93
511260	2.4E-09	0.72	551250	3.5E-11	1.05
511261	3.6E-11	1.08	551270	2.4E-11	0.96
511270	1.7E-09	0.68	551290	6.0E-11	0.90
511280	7.6E-10	0.76	551300	2.8E-11	0.98
511281	3.3E-11	1.48	551310	5.8E-11	0.87
511290	4.2E-10	1.05	551320	5.0E-10	1.00
511300	9.1E-11	0.91	551340	1.9E-08	0.95
511310	1.0E-10	1.00	551341	2.0E-11	1.00
521160	1.7E-10	0.85	551350	2.0E-09	1.00
521210	4.3E-10	1.08	551351	1.9E-11	0.95
521211	2.3E-09	1.15	551360	3.0E-09	1.05
521230	4.4E-09	6.60	551370	1.3E-08	0.65

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
551380	9.2E-11	0.92	601380	6.4E-10	0.96
561260	2.6E-10	1.30	601390	2.0E-11	1.00
561280	2.7E-09	0.81	601391	2.5E-10	1.00
561310	4.5E-10	0.90	601410	8.3E-12	1.25
561311	4.9E-12	0.98	601470	1.1E-09	0.55
561330	1.0E-09	1.00	601490	1.2E-10	0.60
561331	5.5E-10	0.82	601510	3.0E-11	0.90
561351	4.5E-10	0.90	611410	3.6E-11	1.08
561390	1.2E-10	1.20	611430	2.3E-10	0.81
561400	2.5E-09	0.75	611440	9.7E-10	0.97
561410	7.0E-11	1.05	611450	1.1E-10	0.55
561420	3.5E-11	1.23	611460	9.0E-10	0.90
571310	3.5E-11	1.23	611470	2.6E-10	0.65
571320	3.9E-10	0.98	611480	2.7E-09	0.68
571350	3.0E-11	0.90	611481	1.8E-09	0.81
571370	8.1E-11	0.81	611490	9.9E-10	0.50
571380	1.1E-09	0.55	611500	2.6E-10	1.04
571400	2.0E-09	0.80	611510	7.3E-10	0.73
571410	3.6E-10	1.08	621410	3.9E-11	0.98
571420	1.8E-10	0.90	621411	6.5E-11	0.98
571430	5.6E-11	0.84	621420	1.9E-10	0.95
581340	2.5E-09	0.75	621450	2.1E-10	0.74
581350	7.9E-10	0.79	621460	5.4E-08	1.62
581370	2.5E-11	0.88	621470	4.9E-08	1.47
581371	5.4E-10	0.81	621510	9.8E-11	0.49
581390	2.6E-10	0.65	621530	7.4E-10	0.74
581410	7.1E-10	0.71	621550	2.9E-11	1.02
581430	1.1E-09	0.55	621560	2.5E-10	0.88
581440	5.2E-09	0.52	631450	7.5E-10	0.75
591360	3.3E-11	0.99	631460	1.3E-09	0.65
591370	4.0E-11	1.20	631470	4.4E-10	0.66
591381	1.3E-10	1.30	631480	1.3E-09	0.65
591390	3.1E-11	0.93	631490	1.0E-10	0.50
591420	1.3E-09	0.65	631500	1.3E-09	0.65
591421	1.7E-11	0.85	631520	1.4E-09	0.70
591430	1.2E-09	0.60	631521	5.0E-10	1.00
591440	5.0E-11	1.00	631540	2.0E-09	0.70
591450	3.9E-10	0.98	631550	3.2E-10	0.64
591470	3.3E-11	0.99	631560	2.2E-09	0.66
601360	9.9E-11	0.99	631570	6.0E-10	0.90

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
631580	9.4E-11	0.94	681610	8.0E-11	1.20
641450	4.4E-11	1.10	681650	1.9E-11	0.85
641460	9.6E-10	0.48	681690	3.7E-10	0.56
641470	6.1E-10	0.92	681710	3.6E-10	0.90
641480	5.5E-08	1.65	681720	1.0E-09	0.50
641490	4.5E-10	0.68	691620	2.9E-11	1.02
641510	2.0E-10	0.70	691660	2.8E-10	0.98
641520	4.1E-08	1.64	691670	5.6E-10	0.56
641530	2.7E-10	0.68	691700	1.3E-09	0.65
641590	4.9E-10	0.73	691710	1.1E-10	0.55
651470	1.6E-10	0.80	691720	1.7E-09	0.68
651490	2.5E-10	1.00	691730	3.1E-10	0.93
651500	2.5E-10	1.00	691750	2.7E-11	0.94
651510	3.4E-10	0.85	701620	2.3E-11	1.15
651530	2.5E-10	0.75	701660	9.5E-10	0.95
651540	6.5E-10	0.98	701670	6.7E-12	1.00
651550	2.1E-10	0.74	701690	7.1E-10	0.71
651560	1.2E-09	0.60	701750	4.4E-10	0.66
651562	1.7E-10	0.68	701770	9.7E-11	0.97
651561	8.1E-11	0.81	701780	1.2E-10	1.20
651570	3.4E-11	0.85	711690	4.6E-10	0.92
651580	1.1E-09	0.55	711700	9.9E-10	0.99
651600	1.6E-09	0.07	711710	6.7E-10	0.67
651610	7.2E-10	0.72	711720	1.3E-09	0.65
661550	1.3E-10	0.65	711730	2.6E-10	0.78
661570	6.1E-11	0.91	711740	2.7E-10	0.68
661590	1.0E-10	0.50	711741	5.3E-10	0.79
661650	1.1E-10	1.10	711760	1.8E-09	0.72
661660	1.6E-09	0.56	711761	1.7E-10	0.85
671550	3.7E-11	1.11	711770	5.3E-10	0.53
671570	6.5E-12	0.98	711771	1.7E-09	0.68
671590	7.9E-12	1.19	711780	4.7E-11	0.94
671610	1.3E-11	1.30	711781	3.8E-11	0.95
671620	3.3E-12	0.99	711790	2.1E-10	1.05
671621	2.6E-11	1.17	721700	4.8E-10	0.72
671640	9.5E-12	0.95	721720	1.0E-09	0.50
671641	1.6E-11	0.80	721730	2.3E-10	0.92
671660	1.4E-09	0.70	721750	4.1E-10	0.82
671661	2.0E-09	0.90	721771	8.1E-11	1.22
671670	8.3E-11	1.25	721781	4.7E-09	0.94

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
721791	1.2E-09	0.60	751870	5.1E-12	1.27
721801	1.7E-10	0.85	751880	1.4E-09	1.40
721810	1.1E-09	0.55	751881	3.0E-11	1.05
721820	3.0E-09	1.05	751890	7.8E-10	1.17
721821	4.2E-11	1.05	761800	1.7E-11	0.85
721830	7.3E-11	1.10	761810	8.9E-11	0.89
721840	5.2E-10	1.04	761820	5.6E-10	0.84
731720	5.3E-11	1.06	761850	5.1E-10	0.76
731730	1.9E-10	0.95	761891	1.8E-11	0.90
731740	5.7E-11	1.14	761910	5.7E-10	0.57
731750	2.1E-10	0.94	761911	9.6E-11	0.96
731760	3.1E-10	0.93	761930	8.1E-10	0.81
731770	1.1E-10	0.55	761940	2.4E-09	0.60
731780	7.8E-11	1.17	771820	4.8E-11	0.96
731790	6.5E-11	0.65	771840	1.7E-10	0.85
731800	8.4E-10	0.84	771850	2.6E-10	0.91
731801	5.4E-11	0.81	771860	4.9E-10	0.98
731820	1.5E-09	0.68	771870	1.2E-10	1.20
731821	1.2E-11	1.20	771880	6.3E-10	0.94
731830	1.3E-09	0.65	771890	2.4E-10	0.60
731840	6.8E-10	1.02	771900	1.2E-09	0.60
731850	6.8E-11	1.02	771901	8.0E-12	0.80
731860	3.3E-11	0.99	771920	1.4E-09	0.70
741760	1.1E-10	1.10	771921	3.1E-10	0.93
741770	6.1E-11	0.91	771940	1.3E-09	0.65
741780	2.5E-10	0.75	771941	2.1E-09	0.73
741790	3.3E-12	1.15	771950	1.0E-10	1.00
741810	8.2E-11	0.82	771951	2.1E-10	1.05
741850	5.0E-10	0.75	781860	9.3E-11	0.93
741870	7.1E-10	0.71	781880	7.6E-10	0.76
741880	2.3E-09	0.57	781890	1.2E-10	1.20
751770	2.2E-11	1.10	781910	3.4E-10	0.85
751780	2.5E-11	1.00	781930	3.1E-11	0.62
751810	4.2E-10	1.05	781931	4.5E-10	0.68
751820	1.4E-09	1.40	781951	6.3E-10	0.63
751821	2.7E-10	1.08	781970	4.0E-10	0.80
751840	1.0E-09	1.50	781971	8.4E-11	0.84
751841	1.5E-09	1.50	781990	3.9E-11	0.98
751860	1.5E-09	1.50	782000	1.2E-09	0.60
751861	2.2E-09	1.10	791930	1.3E-10	0.65

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
791940	4.2E-10	0.84	822120	5.9E-09	0.59
791950	2.5E-10	0.63	822140	1.4E-10	0.70
791980	1.0E-09	0.50	832000	5.1E-11	1.02
791981	1.3E-09	0.65	832010	1.2E-10	1.20
791990	4.4E-10	0.66	832020	8.9E-11	0.89
792000	6.8E-11	1.02	832030	4.8E-10	0.96
792001	1.1E-09	1.10	832050	9.0E-10	0.90
792010	2.4E-11	1.08	832060	1.9E-09	0.85
801930	8.2E-11	0.82	832070	1.3E-09	0.65
801931	4.0E-10	0.80	832100	1.3E-09	0.65
801940	5.1E-08	1.02	832101	1.5E-08	0.75
801950	9.7E-11	0.97	832120	2.6E-10	1.17
801951	5.6E-10	0.84	832130	2.0E-10	1.00
801970	2.3E-10	0.69	832140	1.1E-10	1.10
801971	4.7E-10	0.70	842030	5.2E-11	1.04
801991	3.1E-11	1.09	842050	5.9E-11	1.18
802030	1.9E-09	0.95	842070	1.4E-10	0.70
811940	8.1E-12	1.22	842100	2.4E-07	1.08
811941	4.0E-11	1.00	852070	2.3E-10	0.92
811950	2.7E-11	1.08	852110	1.1E-08	1.10
811970	2.3E-11	1.15	872220	7.1E-10	1.06
811980	7.3E-11	1.10	872230	2.3E-09	1.04
811981	5.4E-11	1.08	882230	1.0E-07	1.00
811990	2.6E-11	1.04	882240	6.5E-08	0.98
812000	2.0E-10	1.00	882250	9.5E-08	1.43
812010	9.5E-11	1.43	882260	2.8E-07	1.26
812020	4.5E-10	1.13	882270	8.4E-11	1.68
812040	1.3E-09	1.95	882280	6.7E-07	2.35
821951	2.9E-11	1.02	892240	7.0E-10	0.70
821980	1.0E-10	2.50	892250	2.4E-08	0.60
821990	5.4E-11	1.08	892260	1.0E-08	0.50
822000	4.0E-10	0.80	892270	1.1E-06	0.50
822010	1.6E-10	0.80	892280	4.3E-10	0.86
822020	8.7E-09	0.87	902260	3.6E-10	1.08
822021	1.3E-10	1.30	902270	8.9E-09	0.89
822030	2.4E-10	0.72	902280	7.0E-08	1.05
822050	2.8E-10	0.84	902290	4.8E-07	0.96
822090	5.7E-11	1.14	902300	2.1E-07	3.15
822100	6.8E-07	0.68	902310	3.4E-10	0.85
822110	1.8E-10	0.90	902320	2.2E-07	0.55

Table A.1 *Continued.*

Nuclide	Coefficient	Ratio	Nuclide	Coefficient	Ratio
902340	3.4E-09	0.68	942460	3.3E-09	0.66
912280	7.8E-10	0.78	952370	1.8E-11	0.90
912300	9.2E-10	0.46	952380	3.2E-11	1.12
912310	7.1E-07	0.36	952390	2.4E-10	0.96
912320	7.2E-10	0.72	952400	5.8E-10	0.87
912330	8.7E-10	0.87	952410	2.0E-07	0.30
912340	5.1E-10	1.02	952420	3.0E-10	0.75
922300	5.5E-08	0.55	952421	1.9E-07	0.38
922310	2.8E-10	0.70	952430	2.0E-07	0.30
922320	3.3E-07	3.30	952440	4.6E-10	0.92
922330	5.0E-08	1.75	952441	2.9E-11	1.02
922340	4.9E-08	1.72	952450	6.2E-11	1.55
922350	4.6E-08	1.61	952460	5.8E-11	1.16
922360	4.6E-08	1.61	952461	3.4E-11	1.02
922370	7.7E-10	0.77	962380	8.0E-11	1.20
922380	4.4E-08	1.76	962400	7.6E-09	0.38
922390	2.8E-11	0.98	962410	9.1E-10	0.46
922400	1.1E-09	1.10	962420	1.2E-08	0.54
932320	9.7E-12	0.97	962430	1.5E-07	0.38
932330	2.2E-12	1.10	962440	1.2E-07	0.36
932340	8.1E-10	1.22	962450	2.1E-07	0.31
932350	5.3E-11	0.53	962460	2.1E-07	0.31
932360	1.7E-08	0.17	962470	1.9E-07	0.38
932361	1.9E-10	0.57	962480	7.7E-07	0.35
932370	1.1E-07	0.17	962490	3.1E-11	1.24
932380	9.1E-10	0.91	962500	4.4E-06	0.44
932390	8.0E-10	0.80	972450	5.7E-10	0.57
932400	8.2E-11	1.23	972460	4.8E-10	0.96
942340	1.6E-10	0.80	972470	3.5E-07	0.52
942350	2.1E-12	1.05	972490	9.7E-10	0.48
942360	8.6E-08	0.43	972500	1.4E-10	1.40
942370	1.0E-10	0.50	982440	7.0E-11	1.05
942380	2.3E-07	0.46	982460	3.3E-09	0.66
942390	2.5E-07	0.50	982480	2.8E-08	0.56
942400	2.5E-07	0.50	982490	3.5E-07	0.52
942410	4.7E-09	0.47	982500	1.6E-07	0.48
942420	2.4E-07	0.48	982510	3.6E-07	0.54
942430	8.5E-11	0.85	982520	9.0E-08	0.45
942440	2.4E-07	0.48	982530	1.4E-09	0.49
942450	7.2E-10	1.08	982540	4.0E-07	0.60

## APPENDIX B. DOSE TABLES OF NUCLIDES AND DAUGHTERS

Table B.1 *Radiotoxicity per mole of a nuclide and all daughter products (Sv/mole) based on ICRP-68 [2] as a function of the storage time.*

Nuclide	Storage time (a)		
	1.0E+01	2.0E+01	5.0E+01
902300	3.71E+04	3.76E+04	3.96E+04
902320	7.24E-01	8.97E-01	9.69E-01
912310	4.20E+05	5.16E+05	6.75E+05
912330	4.20E+03	4.25E+03	4.39E+03
922320	8.08E+07	7.38E+07	5.48E+07
922330	4.20E+03	4.25E+03	4.39E+03
922340	2.64E+03	2.64E+03	2.64E+03
922350	8.74E-01	8.79E-01	8.97E-01
922360	2.60E+01	2.60E+01	2.60E+01
922370	6.85E+02	6.85E+02	6.85E+02
922380	1.40E-01	1.40E-01	1.40E-01
932370	6.85E+02	6.85E+02	6.85E+02
932380	3.21E+07	2.96E+07	2.34E+07
932390	1.37E+05	1.37E+05	1.37E+05
942380	3.21E+07	2.96E+07	2.34E+07
942390	1.37E+05	1.37E+05	1.37E+05
942400	5.03E+05	5.03E+05	5.01E+05
942410	4.98E+06	5.36E+06	5.66E+06
942420	8.50E+03	8.50E+03	8.50E+03
942430	3.60E+05	3.60E+05	3.60E+05
942440	3.99E+01	4.00E+01	4.01E+01
952410	6.02E+06	5.92E+06	5.64E+06
952421	1.91E+07	1.94E+07	1.98E+07
952420	2.68E+07	2.47E+07	1.95E+07
952430	3.60E+05	3.60E+05	3.60E+05
962420	3.22E+07	2.98E+07	2.35E+07
962430	5.25E+07	4.17E+07	2.09E+07
962440	6.00E+07	4.10E+07	1.34E+07
962450	3.30E+05	3.34E+05	3.47E+05
962460	5.86E+05	5.86E+05	5.83E+05
962470	1.57E+02	1.57E+02	1.58E+02
962480	3.00E+04	3.00E+04	3.00E+04
972490	1.30E+07	1.27E+07	1.20E+07
982490	1.29E+07	1.27E+07	1.20E+07
982500	9.55E+07	5.64E+07	1.20E+07
982510	5.26E+06	5.22E+06	5.10E+06
982520	3.28E+07	2.41E+06	2.99E+04
982530	1.47E+07	1.44E+07	1.36E+07
992530	1.39E+07	1.36E+07	1.28E+07

Table B.1 *Continued.*

Nuclide	Storage time (a)		
	1.0E+02	2.0E+02	5.0E+02
902300	4.37E+04	5.22E+04	7.76E+04
902320	9.71E-01	9.71E-01	9.71E-01
912310	7.53E+05	7.71E+05	7.67E+05
912330	4.62E+03	5.08E+03	6.44E+03
922320	3.34E+07	1.24E+07	6.28E+05
922330	4.62E+03	5.08E+03	6.44E+03
922340	2.65E+03	2.66E+03	2.72E+03
922350	9.33E-01	1.01E+00	1.25E+00
922360	2.60E+01	2.60E+01	2.60E+01
922370	6.85E+02	6.86E+02	6.86E+02
922380	1.40E-01	1.40E-01	1.41E-01
932370	6.85E+02	6.86E+02	6.86E+02
932380	1.57E+07	7.14E+06	6.69E+05
932390	1.37E+05	1.36E+05	1.35E+05
942380	1.57E+07	7.14E+06	6.69E+05
942390	1.37E+05	1.36E+05	1.35E+05
942400	4.99E+05	4.93E+05	4.78E+05
942410	5.37E+06	4.59E+06	2.84E+06
942420	8.50E+03	8.50E+03	8.49E+03
942430	3.59E+05	3.56E+05	3.50E+05
942440	4.03E+01	4.07E+01	4.20E+01
952410	5.21E+06	4.44E+06	2.74E+06
952421	1.89E+07	1.50E+07	4.75E+06
952420	1.31E+07	5.96E+06	5.60E+05
952430	3.59E+05	3.56E+05	3.50E+05
962420	1.58E+07	7.18E+06	6.73E+05
962430	6.68E+06	7.86E+05	1.36E+05
962440	2.39E+06	5.36E+05	4.79E+05
962450	3.68E+05	4.06E+05	4.82E+05
962460	5.79E+05	5.71E+05	5.46E+05
962470	1.59E+02	1.60E+02	1.65E+02
962480	2.99E+04	2.99E+04	2.99E+04
972490	1.09E+07	9.03E+06	5.19E+06
982490	1.09E+07	9.01E+06	5.18E+06
982500	1.38E+06	5.76E+05	5.47E+05
982510	4.91E+06	4.54E+06	3.60E+06
982520	2.90E+04	2.90E+04	2.90E+04
982530	1.23E+07	1.02E+07	5.88E+06
992530	1.17E+07	9.64E+06	5.55E+06

Table B.1 *Continued.*

Nuclide	Storage time (a)		
	1.0E+03	2.0E+03	5.0E+03
902300	1.10E+05	1.57E+05	2.16E+05
902320	9.71E-01	9.71E-01	9.71E-01
912310	7.59E+05	7.43E+05	6.97E+05
912330	8.61E+03	1.26E+04	2.26E+04
922320	4.38E+03	2.13E-01	2.45E-14
922330	8.61E+03	1.26E+04	2.26E+04
922340	2.85E+03	3.22E+03	4.82E+03
922350	1.63E+00	2.37E+00	4.49E+00
922360	2.60E+01	2.60E+01	2.60E+01
922370	6.87E+02	6.90E+02	7.07E+02
922380	1.41E-01	1.41E-01	1.43E-01
932370	6.87E+02	6.90E+02	7.07E+02
932380	1.56E+04	3.17E+03	4.75E+03
932390	1.33E+05	1.29E+05	1.19E+05
942380	1.56E+04	3.17E+03	4.75E+03
942390	1.33E+05	1.29E+05	1.19E+05
942400	4.53E+05	4.08E+05	2.97E+05
942410	1.27E+06	2.57E+05	2.80E+03
942420	8.48E+03	8.47E+03	8.42E+03
942430	3.40E+05	3.22E+05	2.73E+05
942440	4.40E+01	4.77E+01	5.68E+01
952410	1.23E+06	2.49E+05	2.73E+03
952421	4.70E+05	6.10E+03	5.28E+03
952420	1.45E+04	4.10E+03	5.40E+03
952430	3.40E+05	3.22E+05	2.73E+05
962420	1.57E+04	3.17E+03	4.75E+03
962430	1.34E+05	1.30E+05	1.19E+05
962440	4.55E+05	4.09E+05	2.98E+05
962450	5.39E+05	5.46E+05	4.39E+05
962460	5.08E+05	4.40E+05	2.87E+05
962470	1.72E+02	1.87E+02	2.25E+02
962480	2.99E+04	2.98E+04	2.97E+04
972490	2.26E+06	7.88E+05	4.58E+05
982490	2.26E+06	7.87E+05	4.58E+05
982500	5.09E+05	4.41E+05	2.87E+05
982510	2.45E+06	1.13E+06	1.12E+05
982520	2.90E+04	2.89E+04	2.87E+04
982530	2.56E+06	8.91E+05	5.18E+05
992530	2.42E+06	8.41E+05	4.90E+05

Table B.1 *Continued.*

Nuclide	Storage time (a)		
	1.0E+04	2.0E+04	5.0E+04
902300	2.27E+05	2.10E+05	1.59E+05
902320	9.71E-01	9.71E-01	9.71E-01
912310	6.27E+05	5.08E+05	2.69E+05
912330	3.36E+04	4.37E+04	4.48E+04
922320	2.46E-29	3.18E-29	3.25E-29
922330	3.36E+04	4.37E+04	4.48E+04
922340	7.91E+03	1.38E+04	2.84E+04
922350	7.75E+00	1.33E+01	2.44E+01
922360	2.60E+01	2.60E+01	2.59E+01
922370	7.52E+02	8.78E+02	1.31E+03
922380	1.48E-01	1.65E-01	2.71E-01
932370	7.52E+02	8.78E+02	1.31E+03
932380	7.83E+03	1.37E+04	2.84E+04
932390	1.03E+05	7.72E+04	3.26E+04
942380	7.83E+03	1.37E+04	2.84E+04
942390	1.03E+05	7.72E+04	3.26E+04
942400	1.75E+05	6.10E+04	2.59E+03
942410	7.46E+02	8.69E+02	1.30E+03
942420	8.34E+03	8.19E+03	7.75E+03
942430	2.12E+05	1.36E+05	4.84E+04
942440	6.68E+01	7.62E+01	8.09E+01
952410	7.46E+02	8.69E+02	1.30E+03
952421	7.82E+03	1.27E+04	2.48E+04
952420	7.95E+03	1.28E+04	2.49E+04
952430	2.12E+05	1.36E+05	4.84E+04
962420	7.83E+03	1.37E+04	2.84E+04
962430	1.03E+05	7.74E+04	3.27E+04
962440	1.76E+05	6.11E+04	2.60E+03
962450	2.86E+05	1.27E+05	1.21E+04
962460	1.42E+05	3.92E+04	8.22E+03
962470	2.77E+02	3.51E+02	4.58E+02
962480	2.94E+04	2.88E+04	2.71E+04
972490	2.99E+05	1.32E+05	1.25E+04
982490	2.98E+05	1.32E+05	1.25E+04
982500	1.42E+05	3.92E+04	8.22E+03
982510	2.62E+03	3.44E+02	4.55E+02
982520	2.84E+04	2.79E+04	2.62E+04
982530	3.38E+05	1.50E+05	1.42E+04
992530	3.19E+05	1.42E+05	1.34E+04

Table B.1 *Continued.*

Nuclide	Storage time (a)		
	1.0E+05	2.0E+05	5.0E+05
902300	1.01E+05	4.01E+04	2.54E+03
902320	9.71E-01	9.71E-01	9.71E-01
912310	9.34E+04	1.13E+04	1.97E+01
912330	3.64E+04	2.36E+04	6.39E+03
922320	2.64E-29	1.55E-30	4.19E-31
922330	3.64E+04	2.36E+04	6.39E+03
922340	4.12E+04	4.67E+04	2.63E+04
922350	3.26E+01	3.64E+01	3.69E+01
922360	2.59E+01	2.58E+01	2.56E+01
922370	1.94E+03	2.93E+03	3.81E+03
922380	5.47E-01	1.25E+00	2.98E+00
932370	1.94E+03	2.93E+03	3.81E+03
932380	4.12E+04	4.67E+04	2.63E+04
932390	7.76E+03	4.72E+02	3.70E+01
942380	4.12E+04	4.67E+04	2.63E+04
942390	7.76E+03	4.72E+02	3.70E+01
942400	3.90E+01	2.58E+01	2.56E+01
942410	1.94E+03	2.93E+03	3.80E+03
942420	7.06E+03	5.86E+03	3.36E+03
942430	1.12E+04	6.63E+02	3.70E+01
942440	8.11E+01	8.11E+01	8.09E+01
952410	1.94E+03	2.93E+03	3.80E+03
952421	3.53E+04	3.97E+04	2.24E+04
952420	3.55E+04	3.98E+04	2.25E+04
952430	1.12E+04	6.63E+02	3.70E+01
962420	4.12E+04	4.67E+04	2.63E+04
962430	7.78E+03	4.73E+02	3.70E+01
962440	3.90E+01	2.58E+01	2.56E+01
962450	1.98E+03	2.84E+03	3.79E+03
962460	7.15E+03	5.94E+03	3.40E+03
962470	5.11E+02	5.09E+02	5.19E+02
962480	2.44E+04	1.99E+04	1.09E+04
972490	1.98E+03	2.83E+03	3.79E+03
982490	1.98E+03	2.83E+03	3.79E+03
982500	7.14E+03	5.93E+03	3.40E+03
982510	5.11E+02	5.09E+02	5.19E+02
982520	2.37E+04	1.93E+04	1.05E+04
982530	2.24E+03	3.21E+03	4.28E+03
992530	2.11E+03	3.03E+03	4.05E+03

## APPENDIX C. DOSE PLOTS OF NUCLIDES AND DAUGHTERS

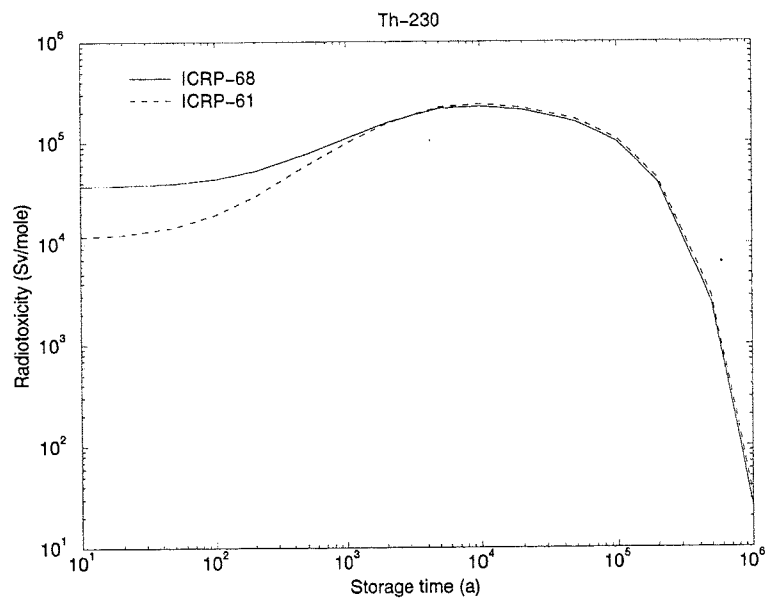


Figure C.1 *The radiotoxicity of  $^{230}\text{Th}$  and all daughter products as a function of the storage time.*

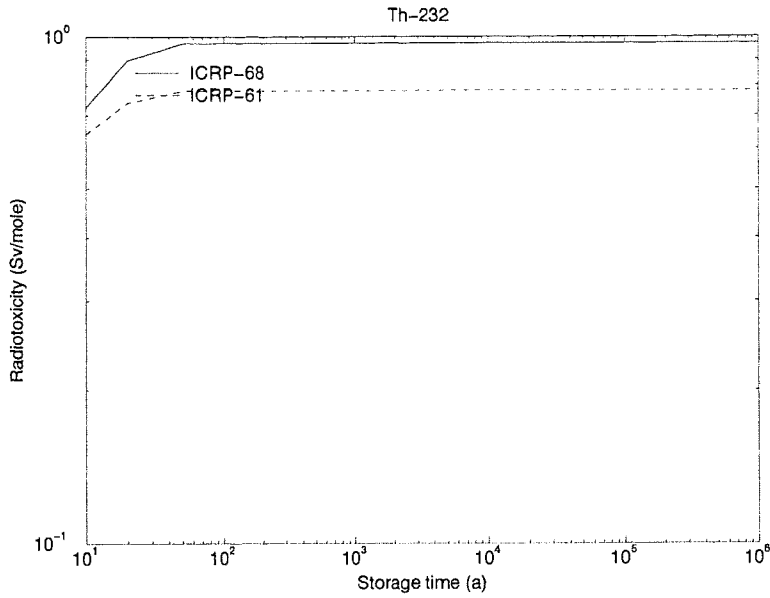


Figure C.2 *The radiotoxicity of  $^{232}\text{Th}$  and all daughter products as a function of the storage time.*

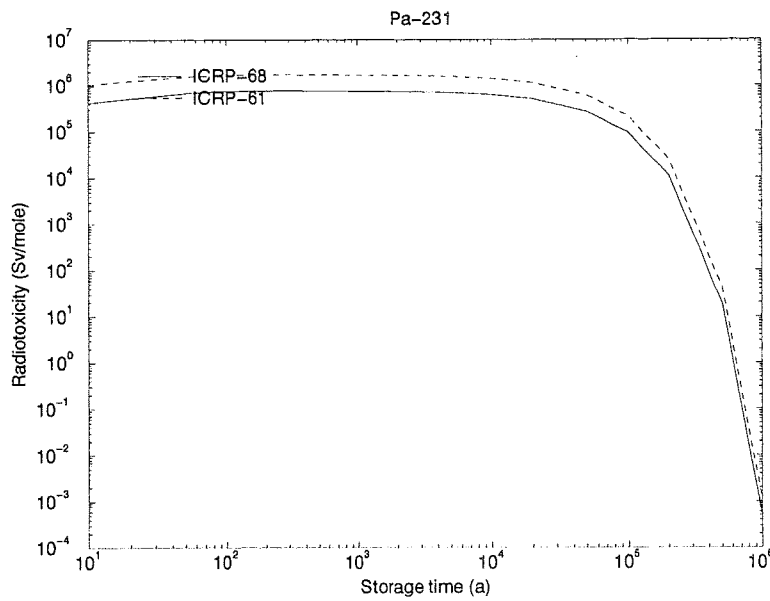


Figure C.3 *The radiotoxicity of  $^{231}\text{Pa}$  and all daughter products as a function of the storage time.*

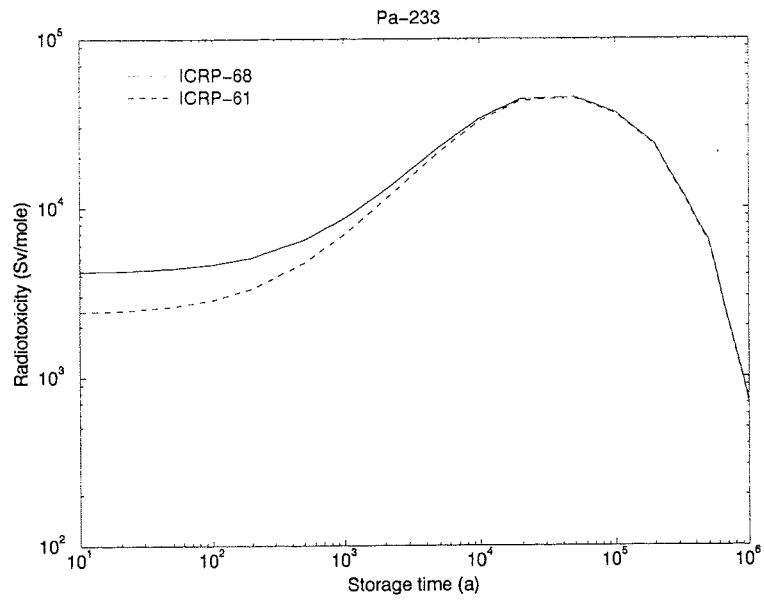


Figure C.4 *The radiotoxicity of  $^{233}\text{Pa}$  and all daughter products as a function of the storage time.*

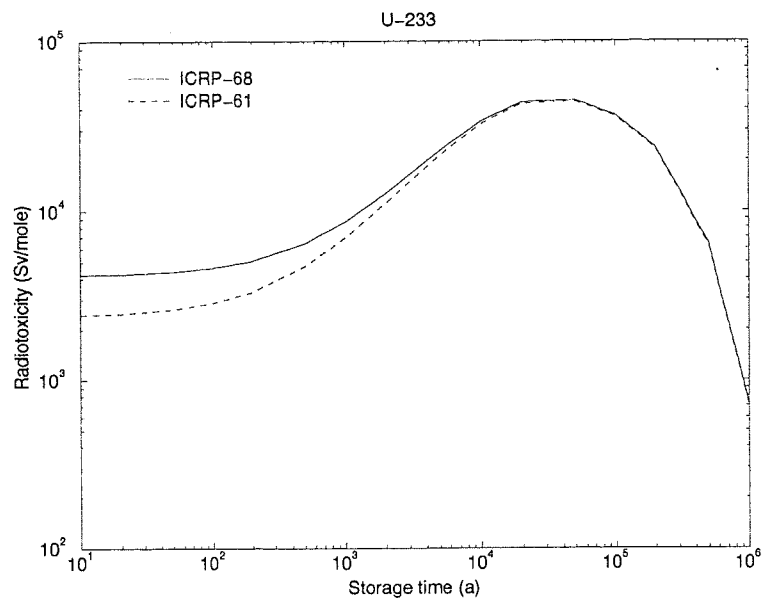


Figure C.5 *The radiotoxicity of  $^{233}\text{U}$  and all daughter products as a function of the storage time.*

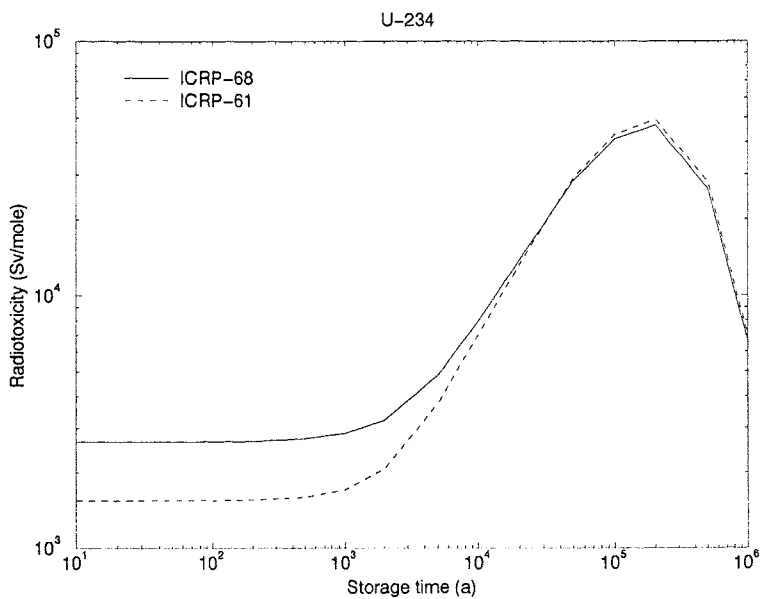


Figure C.6 The radiotoxicity of <sup>234</sup>U and all daughter products as a function of the storage time.

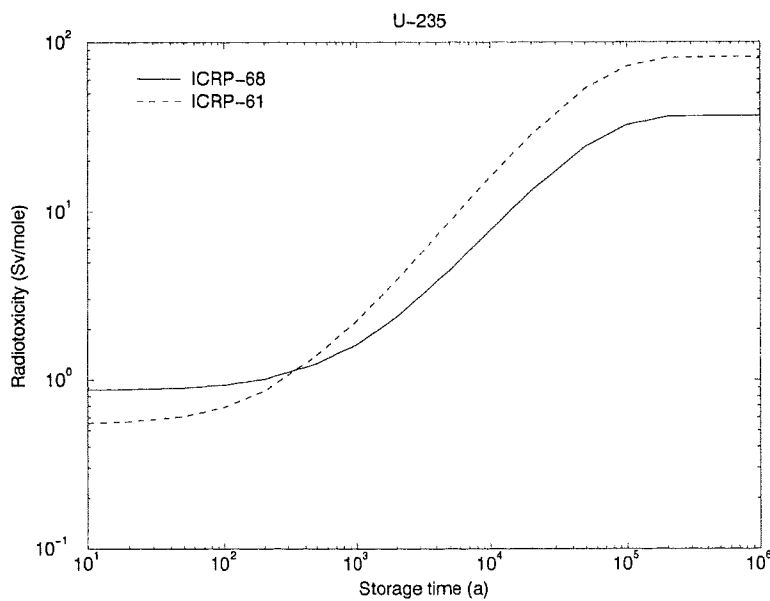


Figure C.7 The radiotoxicity of <sup>235</sup>U and all daughter products as a function of the storage time.

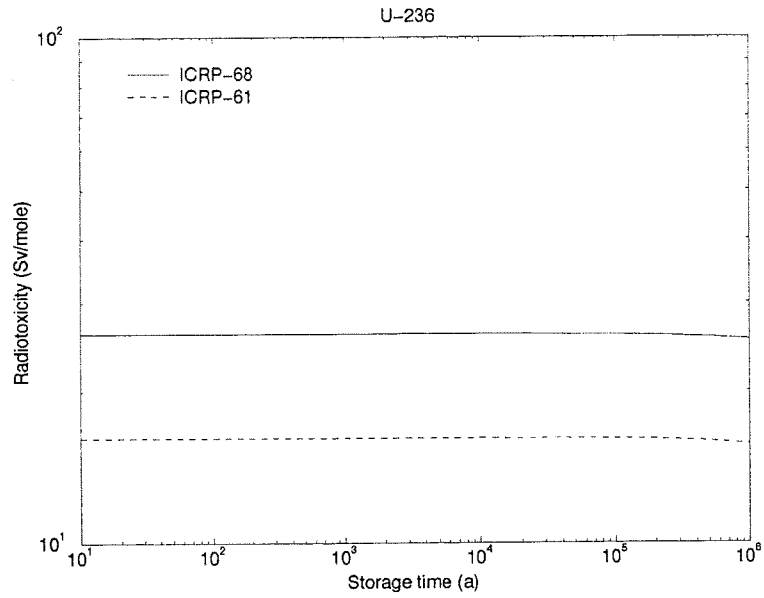


Figure C.8 The radiotoxicity of  $^{236}\text{U}$  and all daughter products as a function of the storage time.

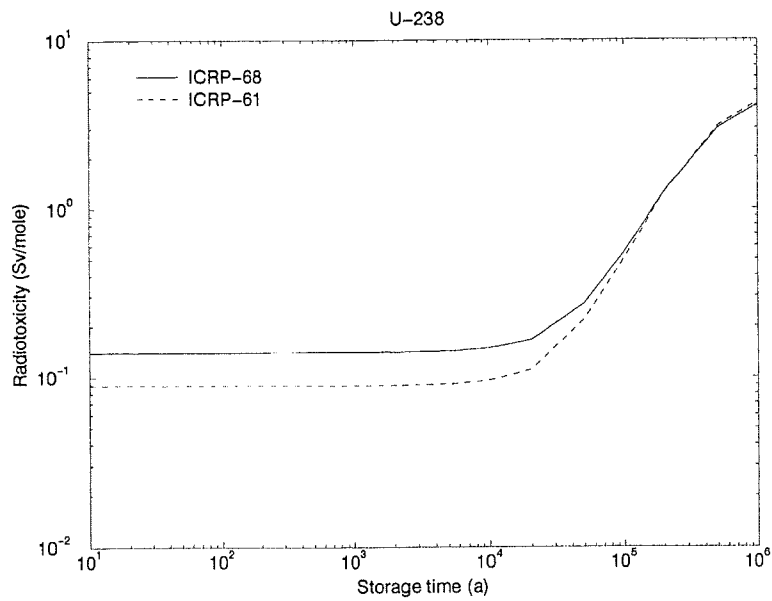


Figure C.9 The radiotoxicity of  $^{238}\text{U}$  and all daughter products as a function of the storage time.

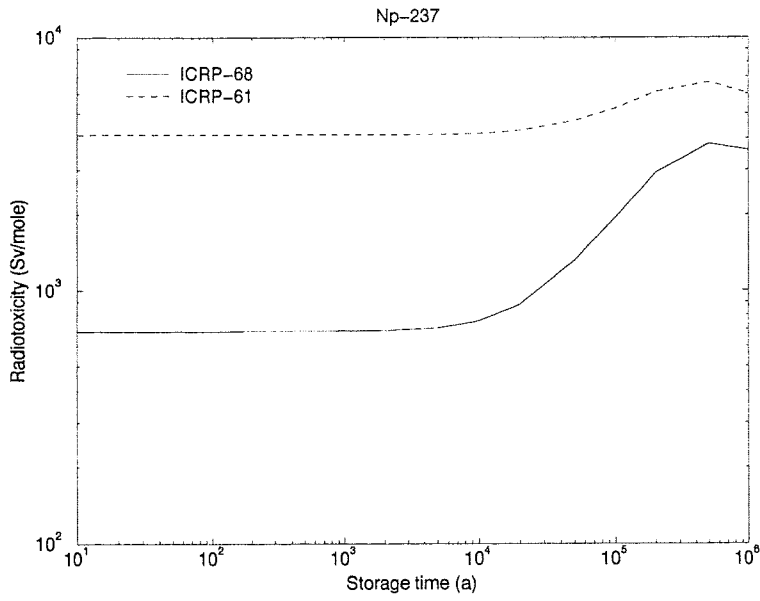


Figure C.10 *The radiotoxicity of <sup>237</sup>Np and all daughter products as a function of the storage time.*

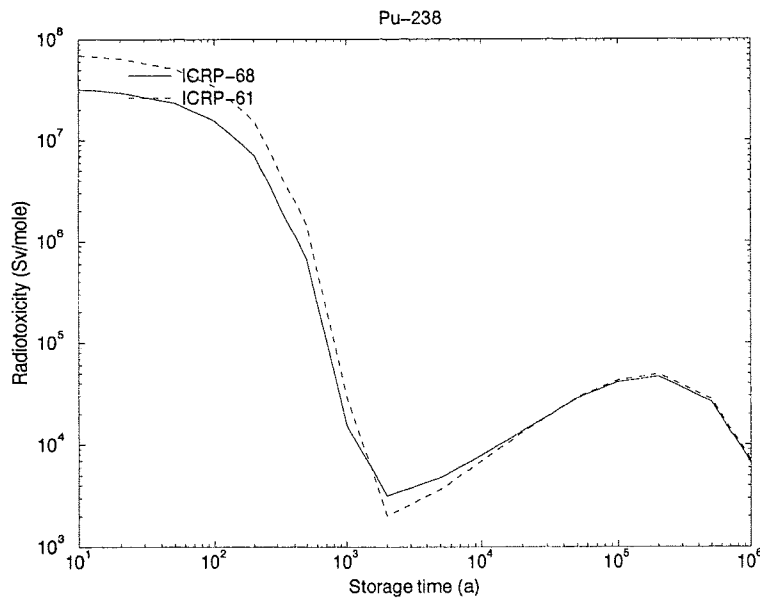


Figure C.11 *The radiotoxicity of <sup>238</sup>Pu and all daughter products as a function of the storage time.*

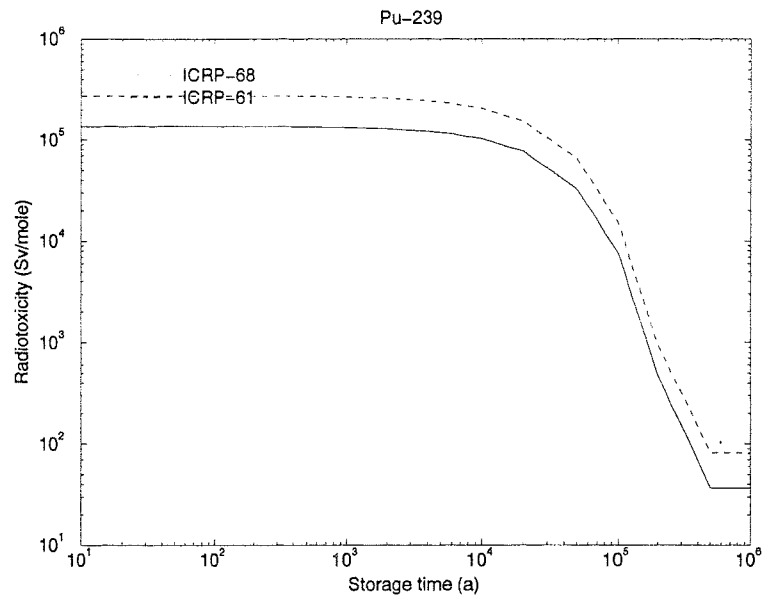


Figure C.12 *The radiotoxicity of  $^{239}\text{Pu}$  and all daughter products as a function of the storage time.*

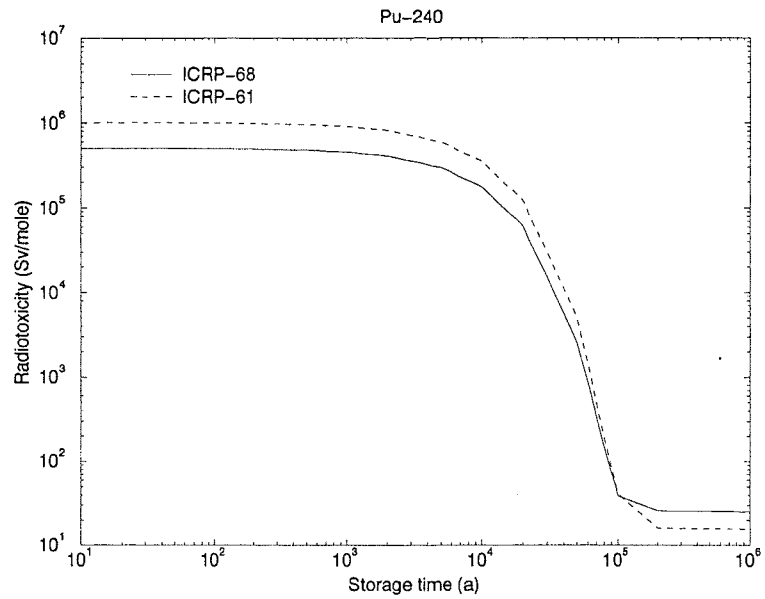


Figure C.13 *The radiotoxicity of  $^{240}\text{Pu}$  and all daughter products as a function of the storage time.*

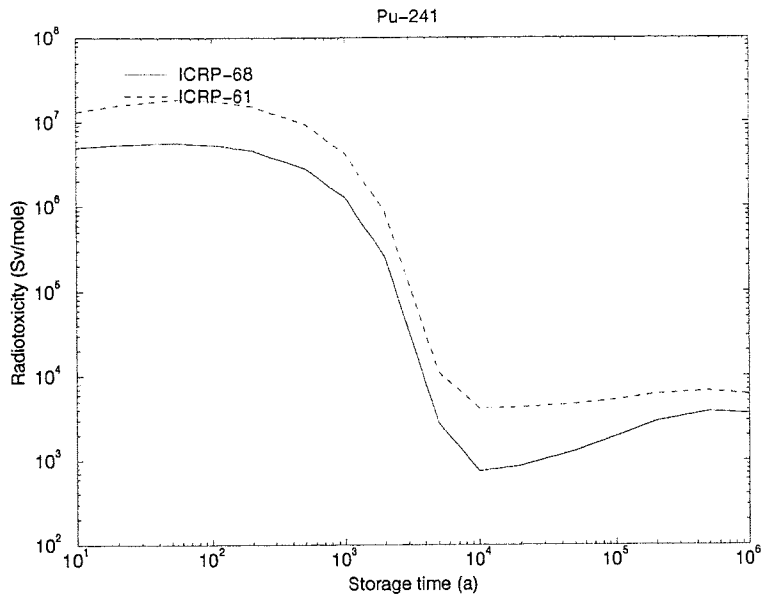


Figure C.14 The radiotoxicity of  $^{241}\text{Pu}$  and all daughter products as a function of the storage time.

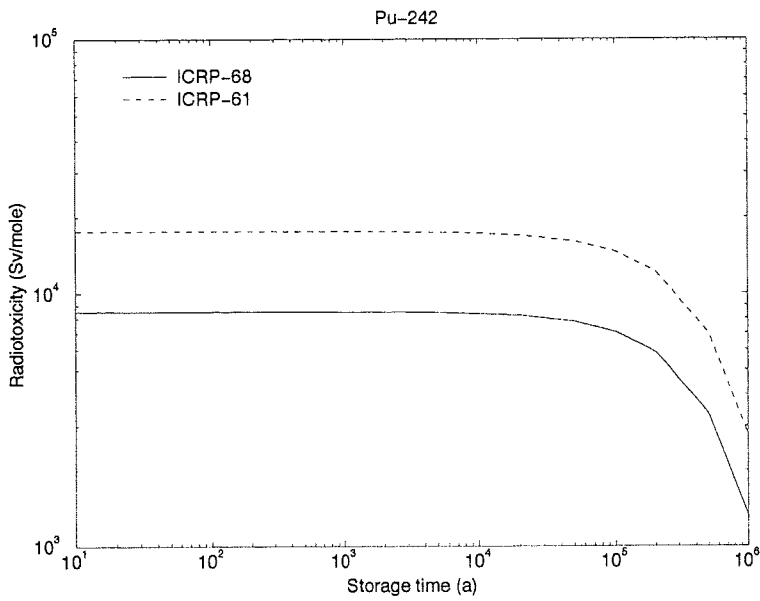


Figure C.15 The radiotoxicity of  $^{242}\text{Pu}$  and all daughter products as a function of the storage time.

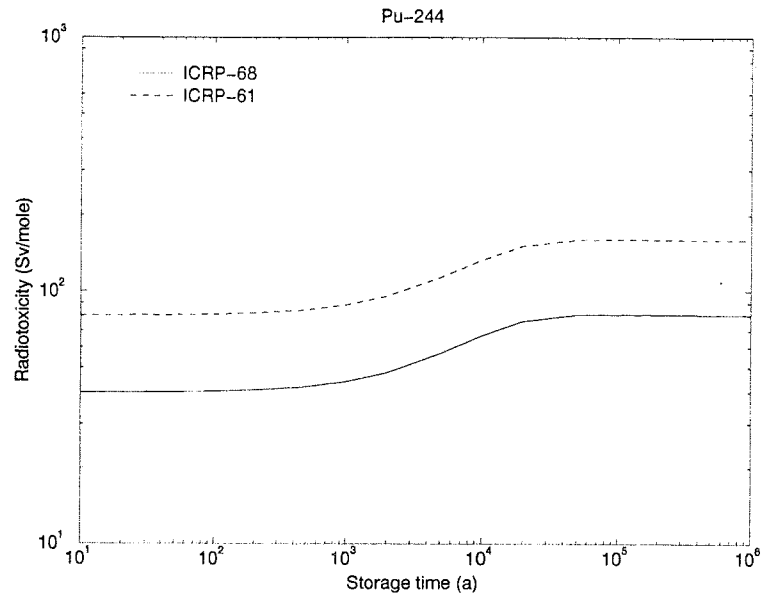


Figure C.16 The radiotoxicity of  $^{244}\text{Pu}$  and all daughter products as a function of the storage time.

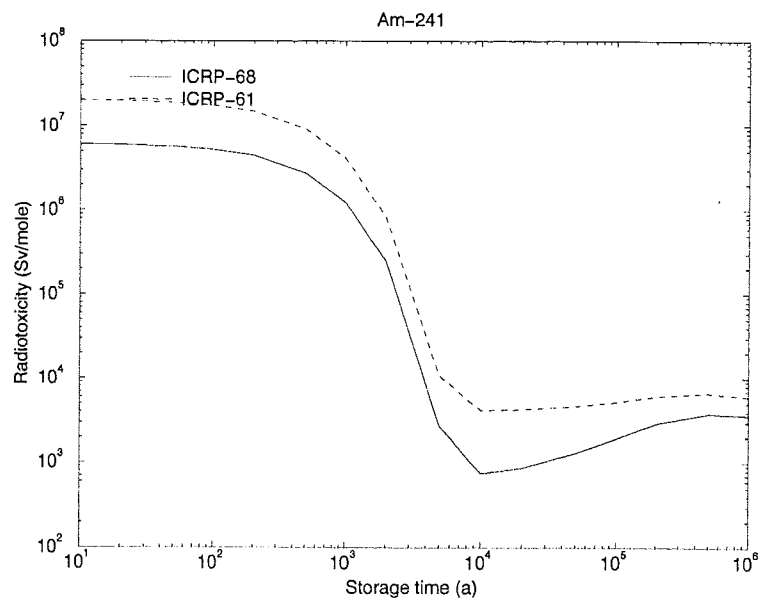


Figure C.17 The radiotoxicity of  $^{241}\text{Am}$  and all daughter products as a function of the storage time.

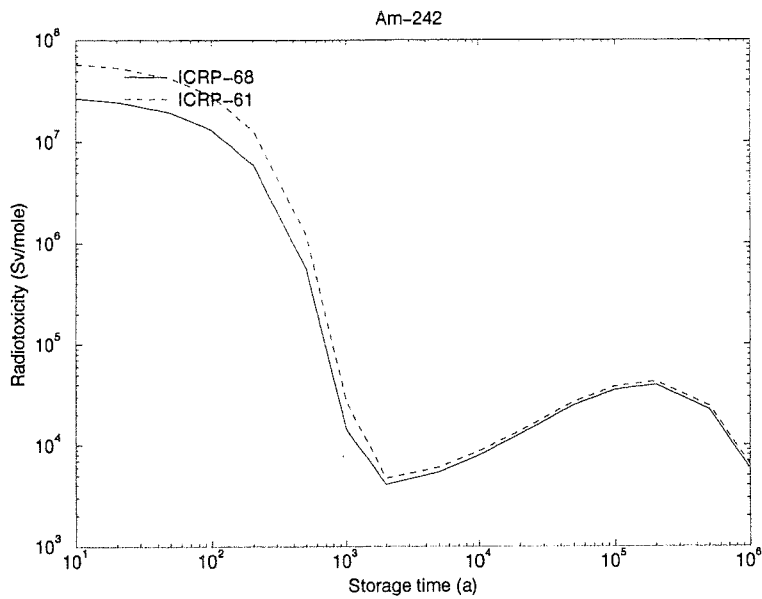


Figure C.18 *The radiotoxicity of <sup>242</sup>Am and all daughter products as a function of the storage time.*

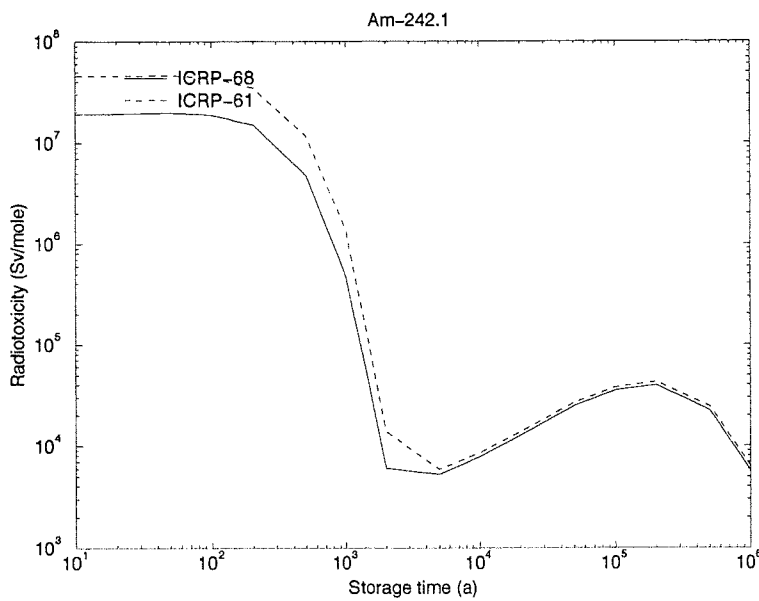


Figure C.19 *The radiotoxicity of <sup>242.1</sup>Am and all daughter products as a function of the storage time.*

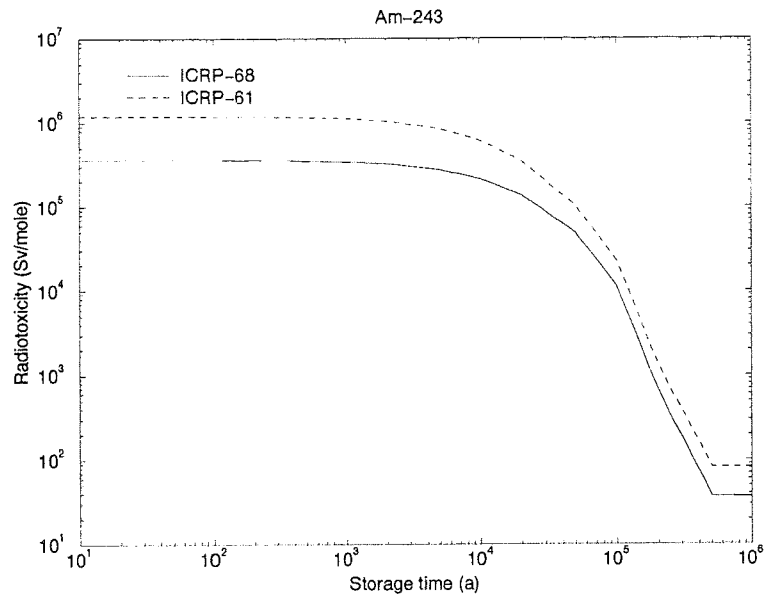


Figure C.20 The radiotoxicity of  $^{243}\text{Am}$  and all daughter products as a function of the storage time.

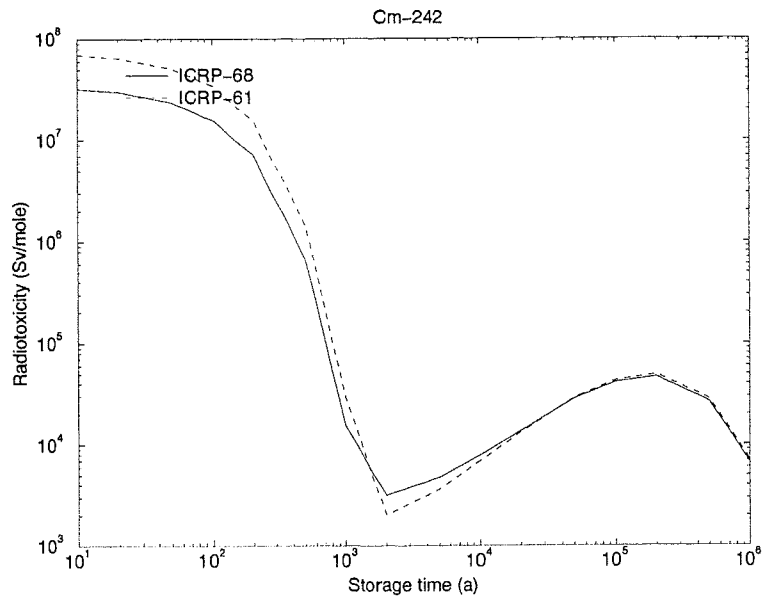


Figure C.21 The radiotoxicity of  $^{242}\text{Cm}$  and all daughter products as a function of the storage time.

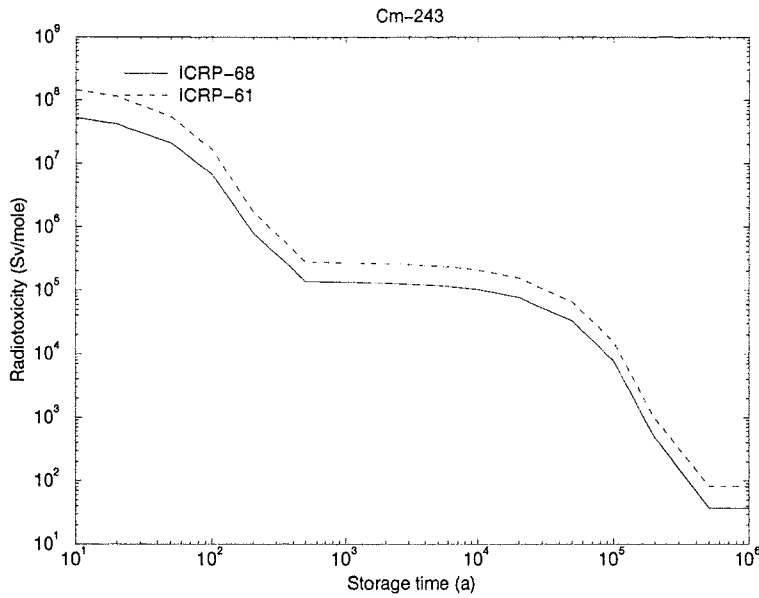


Figure C.22 The radiotoxicity of <sup>243</sup>Cm and all daughter products as a function of the storage time.

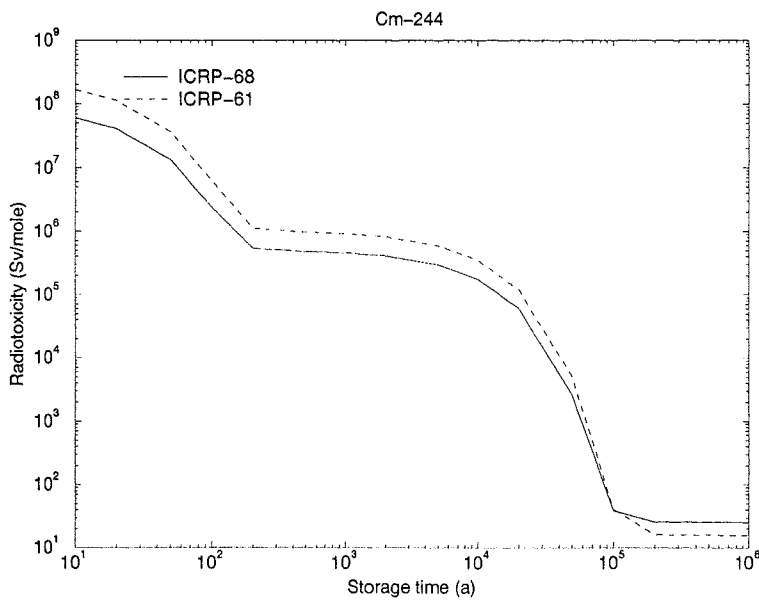


Figure C.23 The radiotoxicity of <sup>244</sup>Cm and all daughter products as a function of the storage time.

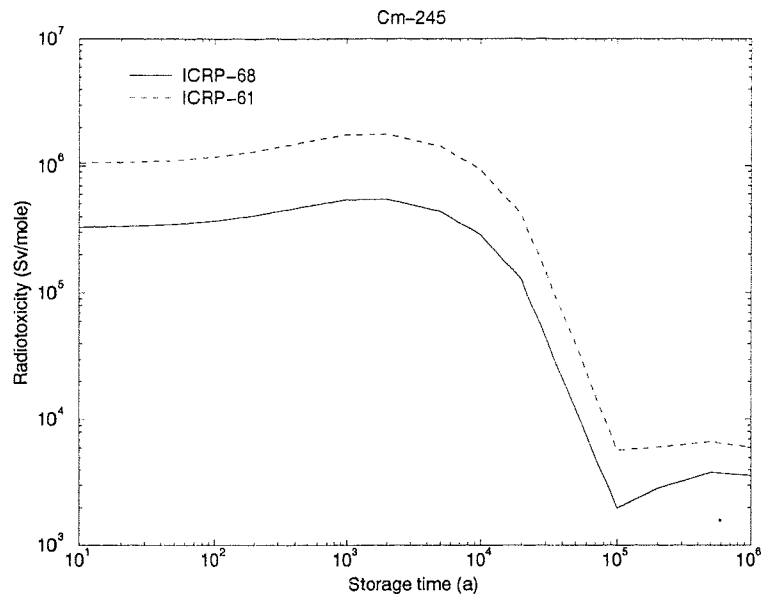


Figure C.24 *The radiotoxicity of <sup>245</sup>Cm and all daughter products as a function of the storage time.*

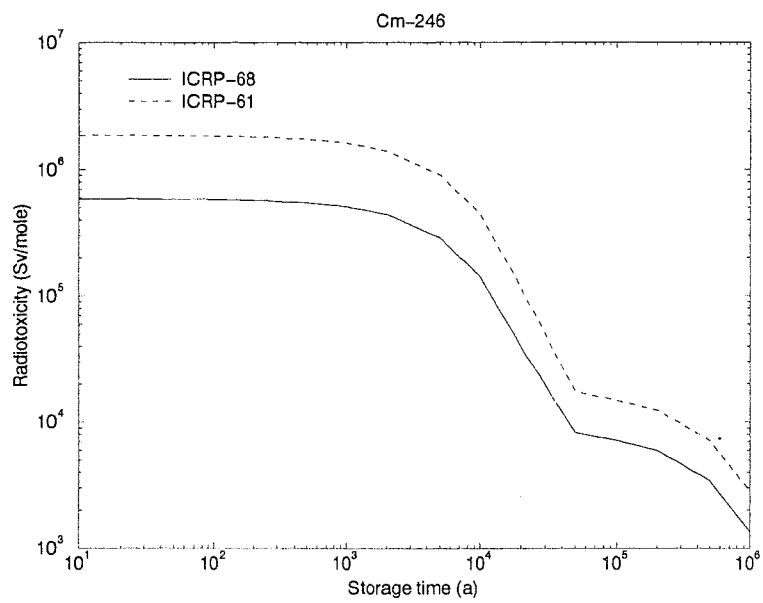


Figure C.25 *The radiotoxicity of <sup>246</sup>Cm and all daughter products as a function of the storage time.*

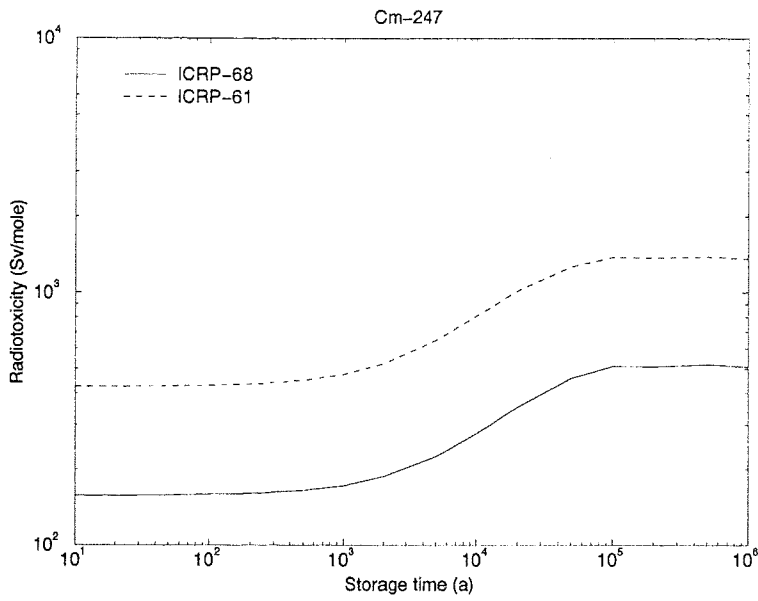


Figure C.26 *The radiotoxicity of  $^{247}\text{Cm}$  and all daughter products as a function of the storage time.*

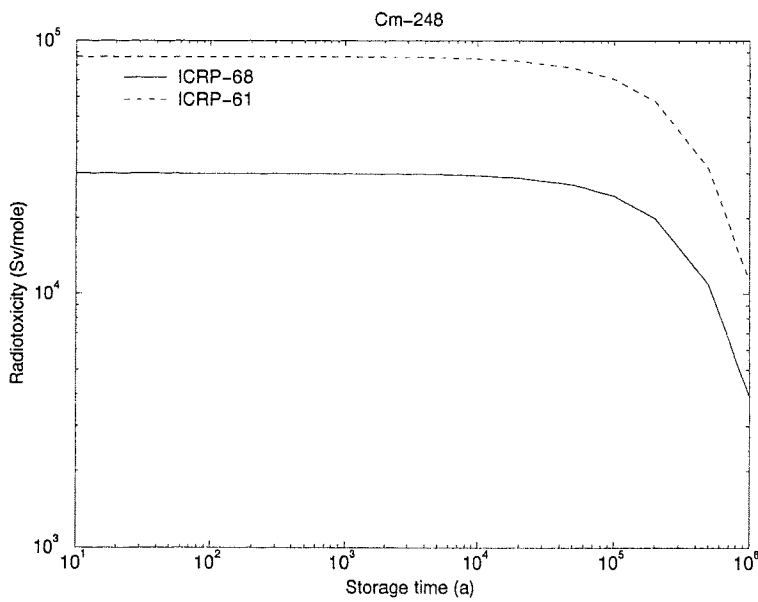


Figure C.27 *The radiotoxicity of  $^{248}\text{Cm}$  and all daughter products as a function of the storage time.*

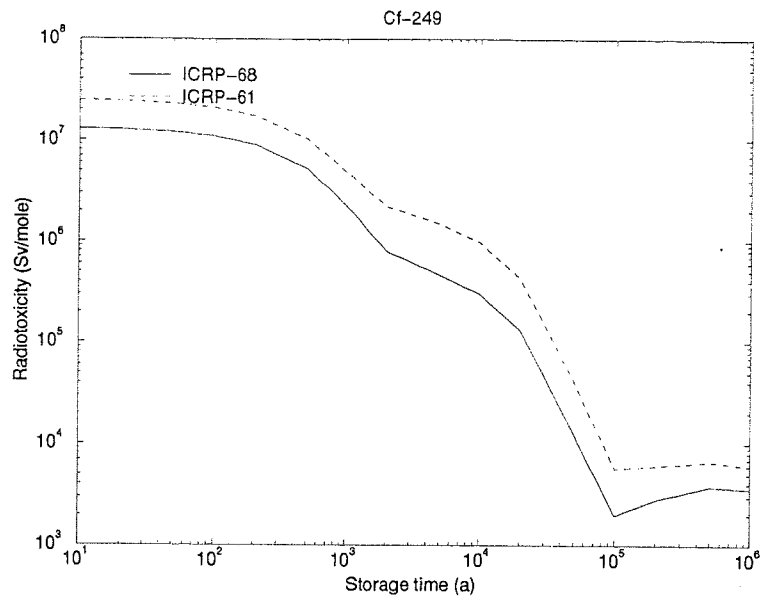


Figure C.28 The radiotoxicity of <sup>249</sup>Cf and all daughter products as a function of the storage time.

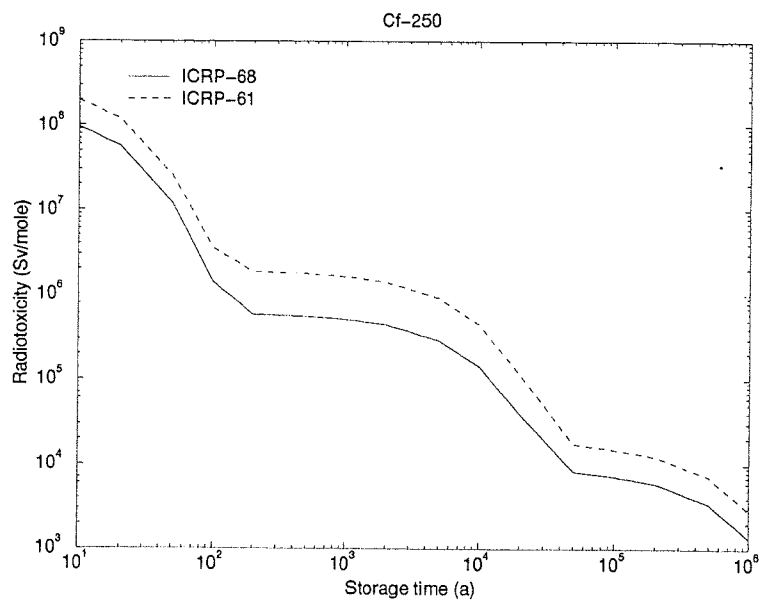


Figure C.29 The radiotoxicity of <sup>250</sup>Cf and all daughter products as a function of the storage time.

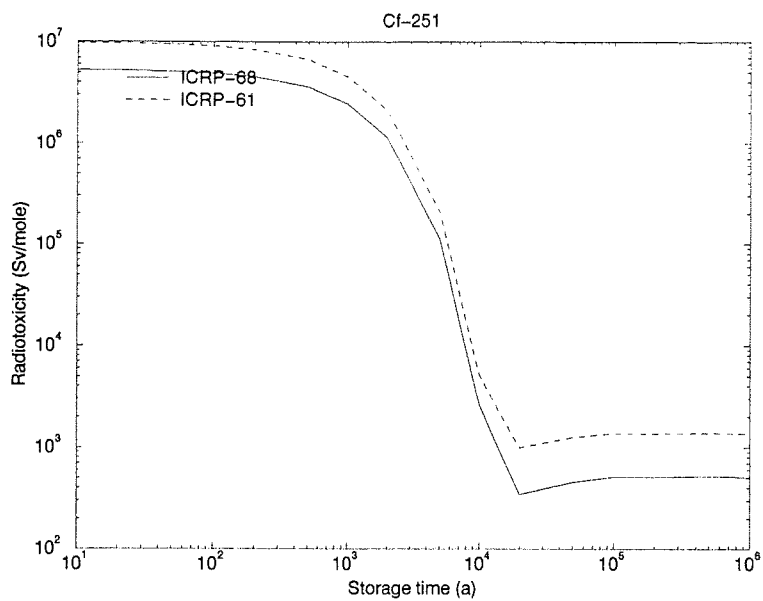


Figure C.30 The radiotoxicity of <sup>251</sup>Cf and all daughter products as a function of the storage time.

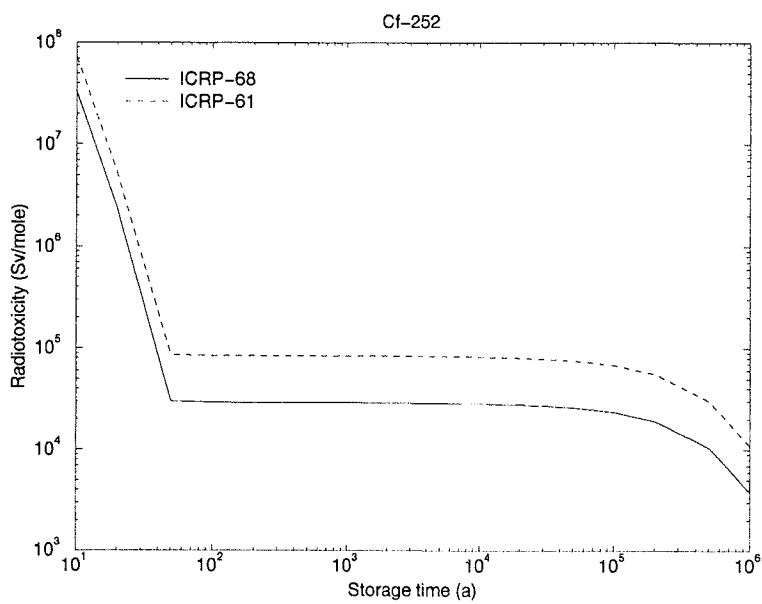


Figure C.31 The radiotoxicity of <sup>252</sup>Cf and all daughter products as a function of the storage time.