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INTEG: A Program to Calculate Groundwater Contamination and Human Dose

F. M. Mann

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Abstract:

INTEG is a computer program to calculate groundwater contamination concentration levels and human dose from inventories, vadose zone transport, and aquifer transport.

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I. OVERVIEW

A. SUMMARY

INTEG is a computer program which integrates values computed by various other programs to provide the long-term consequences of the groundwater pathway. Values are taken from codes producing values for the initial inventory, for the travel through the vadose zone, for the travel through the unconfined aquifer, and for exposure effects.

INTEG is written in standard FORTRAN-77. It was benchmarked on a SUN* SPARC2 workstation.

B. BASIS

A major outcome of environmental analyses is the contamination concentrations and their resultant effects on human beings. These outcomes are not calculated in a single step. Instead a series of calculations are performed which are then combined to find the contaminant concentration and resultant dose. The information needed is:

- 1) The amount of each contaminant [$I_i(0)$] placed in the disposal facility. The amount of each contaminant as a function of time is derived by using the Batemann equation (see below).
- 2) The normalized spatially averaged contaminant flux as a function of time [$i(t)$] at the bottom of the unsaturated (or vadose) zone. The flux is normalized so that the integral over time is unity.
- 3) The area [A] over which the contaminant flux is averaged. Normally, this is taken as the area of the disposal facility.
- 4) The water flux [r] entering the unconfined aquifer from the vadose zone (i.e., the recharge rate).
- 5) The ratio [R] of the contaminant concentration (amount of contaminant per volume of water) in the vadose zone and at the point of interest in the unconfined aquifer.
- 6) Data allowing the calculation of the travel time [δt] in the unconfined aquifer.
- 7) The dose factor [DF_i] which converts contaminant concentration into the dose or risk desired.

From the information items 1 through 6, the contaminant concentration of species i [$C_i(t + \delta t)$] at the point of interest can be calculated from

$$C_i(t + \delta t) = \frac{I_i(t + \delta t) \Gamma_i R}{r A}$$

The dose or risk [$D(t + t)$] can then be calculated from

*SUN SPARC2[®] workstation is a trademark of SUN Microsystems, Inc.

$$D(t+\delta t) = \sum_i DF_i C_i(t+\delta t)$$

The program not only calculates $C_i(t)$ and $D(t)$ but also finds the maximum value (and time of maximum) as well as the time the value passes an user-specified limit.

C. NUCLIDES TRACKED

The seventy-eight radionuclides which are tracked are displayed in Table 1. Table 1 also provides the default associated decay chains, which are used unless overridden by user input (See Section II.A). Note that except for the special case of "am242m" only one decay chain is followed.

Four non-decaying species ("chem-1", "chem-2", "chem-3", and "chem-4") can also be tracked.

Table 1. Radionuclides Tracked.

Nuclide	Default Chain
h 3	-> stable (he 3)
be 10	-> stable (b 10)
c 14	-> stable (n 14)
na 22	-> stable (ne 22)
cl 36	-> stable (s 36 and ar 36)
k 40	-> stable (ar 40 and ca 40)
mn 54	-> stable (cr 54)
fe 55	-> stable (mn 55)
co 60	-> stable (ni 60)
ni 59	-> stable (co 59)
ni 63	-> stable (cu 63)
se 79	-> stable (br 79)
rb 87	-> stable (sr 87)
sr 90	-> y 90 -> stable (zr 90)
zr 93	-> nb 93m
nb 93m	-> stable (nb 93)
nb 94	-> stable (mo 94)
mo 93	-> nb 93m

Nuclide	Default Chain
tc 99	-> stable (ru 99)
ru106	-> rh106 -> stable (pd106)
pd107	-> stable (ag107)
ag108m	-> stable (pd108) small branch through ag108 is effectively included because of the short half life of ag108 and end states are the same.
cd109	-> ag109m -> stable (ag109)
cd113m	-> stable (in113) very small branch (0.1%) to very-long lived cd113 ignored.
in115	-> stable (sn115)
sn121m	-> stable (sn121)
sn126	-> sb126m -> stable (te126) small branch from sb126m to sb126 effectively included because of short half life of sb126 and end states are the same.
sb125	-> stable (te125) small branch through te125m effectively included because of short half life of te125 and the end states are the same.
i 129	-> stable (xe129)
cs134	-> stable (ba134 and xe134)
cs135	-> stable (ba135)
cs137	-> ba137m -> stable (ba137)
ba133	-> stable (cs133)
pm147	-> sm147
sm147	-> stable (nd143)
sm151	-> stable (eu151)
eu150	-> stable (sm150)
eu152	-> stable (sm152) branch to very long lived gd152 (1014 y) ignored.
eu154	-> stable (gd154)
eu155	-> stable (gd155)
gd152	-> stable (sm148)
ho166m	-> stable (er166)
re187	-> stable (os187)
tl204	-> stable (hg204 and pb204)

Nuclide	Default Chain
pb210	-> bi210 -> po210 -> stable (pb206) small branches are ignored because of short half lives and because end states are the same.
bi207	-> stable (pb207) branch through pb207 ignored because of short half-life and because end states are the same.
po209	-> pb205 -> stable (tl205) pb205 decay not considered because of very small dose.
ra226	-> rn222 -> po218 -> pb214 -> bi214 -> po214 -> pb210
ra228	-> ac228 -> th228
ac227	-> th227 -> ra223 -> rn219 -> po215 -> pb211 -> bi211 -> tl207 -> stable (pb207) other branches not considered because of short half-lives and the end states are the same.
th228	-> ra224 -> rn220 -> po216 -> pb212 -> bi212 -> po212 -> stable (pb208) other branches not considered because of short half-lives and the end states are the same.
th229	-> ra225 -> ac225 -> fr221 -> at217 -> bi213 -> po213 -> tl209 -> pb209 -> stable (bi209)
th230	-> ra226
th232	-> ra228
pa231	-> ac227
u 232	-> th228
u 233	-> th229
u 234	-> th230
u 235	-> th231 -> pa231
u 236	-> th232
u 238	-> th234 -> pa234m -> u234 pa234 branch ignored because of short half life and because end state is the same
np237	-> pa233 -> u 233
pu236	-> u 232
pu238	-> u 234
pu239	-> u 235
pu240	-> u 236

Nuclide	Default Chain
pu241	-> am241 small branch 10-5 to u 237 ignored in chain calculations, but dose included as part of pu241 decay
pu242	-> u 238
pu244	-> u 240 -> np240m -> pu240
am241	-> np237
am242m	-> am242m -> pu242 (0.173) -> am242 -> cm242 -> pu238 (0.827) only pair of decay chains considered
am243	-> np239 -> pu239
cm243	-> pu239
cm244	-> pu240
cm245	-> pu241
cm246	-> pu242
cm247	-> pu243 -> am243
cm248	-> pu244 8% spontaneous fission not followed.

II. INPUT

A. USER INPUT

Most of the data used by the program is on various files generated by other programs. The selection of these files and only needed input is specified by the user on the standard input file through the use of keywords. After each keyword command is read, the code acts on the command and puts the result of that action on the standard output file. The available keywords are given in Table 2. A sample input file is given in Section 1 of Appendix A.

Table 2. Input Keywords.

Keyword ^a	Values ^b	Description
invfac	z y w	inventory for radionuclide "z" is multiplied by "y". "w" must be blank.
inv	z y w	inventory for radionuclide "z" is set to "y w". Allowable units for w are "Ci".
invfile	x	inventories are taken from file "x".

Keyword ^a	Values ^b	Description
t12	z y w	half-life for radionuclide "z" is set to "y w". Allowable units for "w" are "y" or "yr".
t12f	x	half lives for radionuclides are taken from file "x".
vadfile	x	vadose transport factors are taken from file "x".
nlabf	x	vadose zone labels for radionuclides are taken from file "x".
nuclab	z v	vadose zone label for radionuclide "z" is set to "v".
area	y w	area of disposal is set to "y w". Allowable units for w are "m2".
geo	y w	area of disposal factor multiplied by "y". "w" must be blank.
recharge	y w	recharge rate is set to "y w". Allowable units for "w" are "mm/y" or "cm/y" or "m/y".
wif	y w	ratio of contaminant concentration in vadose zone to the concentration in the unconfined aquifer at the point of interest is set to "y w". "w" should be blank.
densit	y w	density of the soil in the unconfined aquifer. Allowable units of w are "g/cm3".
kd	y w	Kd for unconfined aquifer is set to "y w". Allowable units for w are "ml/g".
poros	y w	porosity of the unconfined aquifer is set to "y". "w" should be blank.
time	y w	travel time in unconfined aquifer for unretarded contaminants is set to "y w". Allowable units are "y" or "yr" or "d".
all	z y w	all-pathway dose factor for radionuclide z is set to "y w". Allowable units for w are "mrem/y/pCi/l".
allfile	x	all-pathway dose factors are taken from file "x".
dw	z y w	drinking water dose factor for radionuclide z is set to "y w". Allowable units for w are "mrem/y/pCi/l".
dwfile	x	drinking water dose factors are taken from file "x".

Keyword ^a	Values ^b	Description
h2oall	y w	all-pathway dose factors increased by y. This is equivalent to increasing the amount of water consumed in the drinking water scenario. "w" must be blank.
h2odw	y w	all-pathway dose factors increased by y. This is equivalent to increasing the amount of water consumed in the drinking water scenario. "w" must be blank.
all1	y w	limit for the all-pathway dose is set to "y w". Allowable units for w are "mrem/y" or "mrem/yr".
con1	y w	limit on concentration is set to "y w". Allowable units for w are "pCi/m3" or "pCi/l".
conal	y w	limit on concentration of alpha emitters is set to "y w". Allowable units for w are "pCi/m3" or "pCi/l".
conral	y w	limit on radium concentration is set to "y w". Allowable units for w are "pCi/m3" or "pCi/l".
conul	y w	limit on uranium concentration is set to "y w". Allowable units for w are "pCi/m3" or "pCi/l".
dw1	y w	limit on the drinking water dose. Allowable units for w are "mrem/y" or "mrem/yr".
dwal	y w	limit on the drinking water dose for alpha emitters. Allowable units for w are "mrem/y" or "mrem/yr".
dwbl	y w	limit on the drinking water dose for beta/photon emitters. Allowable units for w are "mrem/y" or "mrem/yr".
end		end of user input

a format is (a8,2x)
 b format is
 x: (a64)
 z y w: (a8,2x,f10.0,a16)
 y w: (10x, f10.0,a16)
 v: (10x, a8)

B. INVENTORY FILE

The amount of each contaminant can be specified from user input (command: "inv z y w") or by reading a file (command: "invfile x") or both. Contaminants can be read in any order. Note that the last value read for a given contaminant (either from user input or from a file) is the one used in the calculation. The format for the inventory file is given in Table 3. A sample inventory file is shown in Section 2 of Appendix A.

Table 3. Format of Inventory File.

Line	Input	Description
1	h1,	h1 is "inv" in an a3 format 7x
	h2	h2 is a comment in a64 format
2-n	h1,	h1 is the nuclide label (a8) 2x
	r1	r1 is the amount in Ci (f10.0)

The half-life of each nuclide can be specified from user input (command: "t12 z y w") or by reading a file (command: "t12file x") or both. Contaminants can be read in any order. Note that the last value read for a given contaminant (either from user input or from a file) is the one used in the calculation. The format for the half-life file is given in Table 4. A sample half-life file is displayed in Section 3 of Appendix A.

Table 4. Format of Half-life File.

Line	Input	Description
1	h1,	h1 is "t12" in an a3 format 7x
	h2,	h2 is the time unit ('y', 'yr', or 's') in a2 format
	h3	8x
	h3	h3 is a comment in an a64 format
2-n	h1,	h1 is the nuclide label (a8) 2x
	r1,	r1 is the half-life in the units specified in line 1. (f10.0)
	h3,	h3 is the nuclide label for the daughter. If blank, the default is used. (a6)
	r2,	4x r2 is the fraction of the dose assigned to "beta/gamma emitters". Default = 1. if beta is emitted, 0. if no betas emitted. (f10.0)
	r3,	r3 is the fraction of the dose assigned to "alpha emitters". Default = 1. if alpha is emitted, 0. if no alphas emitted. (f10.0).
	r4,	r4 is the number of "beta/photon emitters" in decay chain. Default is taken from decay chain shown in Table 1. (f10.0)
	r5,	r5 is the number of "alpha emitters" in decay chain. Default is taken from decay chain shown in Table 1. (f10.0)
	r6	r6 is the fraction of decays using this chain. Default =1 except for am242m and cm248 chains. (f10.0)

C. VADOSE ZONE FILE

The spatially averaged normalized contaminant flux at the bottom of the vadose zone is specified or by reading a file (command: "vadfile x"). The format for the inventory file is given in Table 5. A sample vadose zone file is shown in Section 4 of Appendix A.

Table 5. Format of Vadose Zone File.

Line	Input	Description
1	h1, i1, i2, h2	h1 is "VADOSE" in an a6 format 4x i1 is the number of Kd blocks in i10 format i2 is the number of times for which the flux is given (i10) h2 is a comment in a64 format
2	(h1(i), i=1,i1)	12x h1(i) is the block label (a8,4x) 8 sets of label can be read per line
3-n	t(j), (vad(i,j), i=1,i1)	t(j) is time in units of years e12.5 vad is the spatially average normalized flux in e12.5 8 values of vad can be read per line if more values are needed, the 9th value should be in the first 12 spaces.

Each contaminant is linked to a block in the vadose zone file by a nuclide block label. The block label for each contaminant can be specified from user input (command: "nuclab z w") or by reading a file (command: "nlabf x") or both. Contaminants can be read in any order. Note that the last value read for a given contaminant (either from user input or from a file) is the one used in the calculation. The nuclide block labels must be one of the block labels in the vadose zone file. The format for the nuclide block identification file is given in Table 6. A sample nuclide block identification file is shown in Section 5 of Appendix A.

Table 6. Format of Nuclide Block Identification File.

Line	Input	Description
1	h1, h2	h1 is "vadlab" in an a6 format 4x h2 is a comment in a64 format
2-n	h1, h2	h1 is the nuclide label (a8) 2x h2 is the vadose zone block label (a8)

D. DOSE FACTOR FILES

Dose factors are needed for both a drinking water scenario and for an all-pathways scenario. The drinking water dose factor of each contaminant can be specified from user input (command: "dw z y w") or by reading a file (command: "dwfile x") or both. Contaminants can be read in any order. Note that the last value read for a given contaminant (either from user input or from a file) is the one used in the calculation. The format for the inventory file is given in Table 7. A sample drinking water dose factor file is given in Section 6 of Appendix A.

Table 7. Format of Drinking Water Dose Factor File.

Line	Input	Description
1	h1,	h1 is "dw" in an a2 format 8x
	h2,	h2 is the unit (must be 'mrem/y/pCi/l') in a16 format 4x
	h3	h3 is a comment in a64 format
2-n	h1,	h1 is the nuclide label (a8) 2x
	r1	r1 is the drinking water dose factor (f10.0)

The all-pathways dose factor of each contaminant can be specified from user input (command: "all z y w") or by reading a file (command: "allfile x") or both. Contaminants can be read in any order. Note that the last value read for a given contaminant (either from user input or from a file) is the one used in the calculation. The format for the inventory file is given in Table 8. A sample all-pathways dose factor file is given in Section 7 of Appendix A.

Table 8. Format of All-Pathways Dose Factor File.

Line	Input	Description
1	h1,	h1 is "all" in an a2 format 8x
	h2,	h2 is the unit (must be 'mrem/y/pCi/l') in a16 format 4x
	h3	h3 is a comment in a64 format
2-n	h1,	h1 is the nuclide label (a8) 2x
	r1	r1 is the all-pathways dose factor (f10.0)

III. OUTPUT

Output is written to two files, the standard output file and unit 7. The standard output file contains six (6) sections:

- 1) Actions taken based on user input
- 2) Echoing of data to be used in calculations
- 3) Maximum values (and the time they are reached) as well as the time at which user-inputted limit values are reached
- 4) All-pathways and drinking water (total, alpha, and beta/photon) at each time step
- 5) Contributions to drinking water dose rates from Tc, Se, U, and Np at each time step
- 6) Contaminant concentration (total, alpha, radium, and uranium) at each time step

On unit 7, at each time step, the total amount of contaminant (corrected for decay), the concentration at the point of interest, the all-pathways dose, and the drinking water dose (total, alpha, and beta/photon) are given.

Sample output files can be found in the appendix (Section 8 for the standard output file and Section 9 for the fort.7 file).

IV. CODING DETAILS

A. STRUCTURE

The structure of the program is shown in Figure 1. Five "include" files are used:

- 1) flag.h: contains logical variables used in input
- 2) itable.h contains other variables used in input
- 3) otable.h contains variables used in output
- 4) par.h contains parameter variables
- 5) ttable.h contains temporary variables

The FORTRAN program units are

0. integ main program
- 0.1 blkdat initialize data
1. readus read user input
- 1.1 rdall all-pathway dose factor for z set to y
- 1.2 rdalf all-pathway dose factors read from file x
- 1.3 rdall limit for all-pathways dose set to y
- 1.4 rdarea area of disposal facility set to y
- 1.5 rdcon1 limit for total concentration set to y
- 1.6 rdcnal limit for alpha emitter concentration set to y
- 1.7 rdcnrl limit for radium concentration set to y

Figure 1. Structure of Program

1.8	rdcnul	limit for uranium concentration set to y
1.9	rdnden	density of soil in aquifer set to y
1.10	rdwdw	drinking water dose factor for z set to y
1.11	rdddf	drinking water dose factors read from file x
1.12	rdwdwl	limit for drinking water dose set to y
1.13	rdwdwal	limit for drinking water dose from alpha emitters set to y
1.14	rdwdwb1	limit for drinking water dose from beta/photon emitters set to y
1.15	rdgeo	multiplicative factor for area set to y
1.16	rdwall	multiplicative factor for all-pathways dose factors
1.17	rdwdw	multiplicative factor for drinking water dose factors
1.18	rdinfc	multiplicative factor for inventories
1.19	rdinv	inventory for z set to y
1.20	rdinvf	inventories read from file x
1.21	rdkd	kd for aquifer set to y
1.22	rdlabf	vadose block labels read from file x
1.23	rdlab	vadose block label for z set to y
1.24	rdpor	porosity of aquifer set to y
1.25	rdrech	recharge set to y
1.26	rdtl2	half-life for z set to y
1.27	rdtl2f	half-lives read from file x
1.28	rdtime	unretarded travel time in aquifer set to y
1.29	rdvadf	vadose zone fluxes read from file x
1.30	rdwif	well intercept factor set to y
1.31	check input	data is checked for consistency and completeness
1.32	outinp	input data is outputted
2.	respon	calculates and outputs desired quantities
2.1	cdenom	calculate Batemann denominators
2.2	caltim	calculate amount of each contaminate at each time step
2.3	calexp	calculate exposure parameters
u.1	dxpn	$\exp(x)-1$
u.2	fexp	$\exp(x)$
u.3	searcc	place character variable in proper place in nuclide table
u.4	search	place real variable in proper place in nuclide table

B. BATEMANN EQUATION

The most complicated calculation is the calculation of the decay equations. For simple decays, that is, decays involving only a parent and a daughter, the activity of the parent $A(t)$ is

$$A(t) = e^{(-\lambda t)}$$

where λ is the mean life $[=0.693147 / (\text{half-life})]$.

For more complicated decay chains, the Batemann equation is used:

$$\begin{aligned}
 A_n(t) &= A_1(0) B_n L_n T_n(t) \\
 B_n &= \prod_{k=1}^{n-1} B_{k,k+1} \\
 L_n &= \prod_{k=2}^n \lambda_k \\
 T_n(t) &= \sum_{k=1}^n \frac{(e^{-\lambda_k t})}{D_{k,n}} \\
 D_{k,n} &= \prod_{\substack{i=1 \\ i \neq k}}^n (\lambda_i - \lambda_k)
 \end{aligned}$$

where

- $A_n(t)$ = activity on the "nth" member of the decay chain,
 $A_1(0)$ = the initial activity of the first member of the chain,
 $B_{k,k+1}$ = the branching ratios for the k to k+1 nuclide decay step, and
 k = the decay constant for the "kth" member of the chain.

V. VERIFICATION

A. BENCHMARKING

The computer code GRTPA (Rittmann 1993) is the basis for this code. Improvements mainly consist of a more flexible input and a different output structure. Direct comparisons between GRTPA and INTEG are difficult as the basis of the input files is different and the output format is quite different. GRTPA calculates the effect of water dilution by using an aquifer flow rate, while INTEG uses a well intercept factor, the area of the facility, and the amount of water entering the aquifer as input. However, correcting for these differences and in the differences between dose conversion factors, good agreement is found between the INTEG results and the suite of runs for GRTPA (Rittmann 1993). In addition, comparisons with the results from a complex model used in preliminary studies of the Hanford Low-Level Tank Waste Performance Assessment (Kline 1995) showed good agreement.

B. LIMITATIONS

The most significant limitations are the use of the Batemann equations to calculate decay chains and the treatment of retardation for different elements in a decay chain.

The Batemann equations are encoded using single precision variables. Thus for daughters far down the chain and at short times, some numerical instability can exist. Similar instabilities exist for long times (greater

than about 20 half-lives). However, for such conditions the contribution of these nuclides is very small compared to nuclides nearer the parent in the chain. Thus for practical problems, this limitation is not important.

Various elements in a decay chain will be retarded by different amounts during their travel in the vadose zone. Because the current versions of the vadose zone transport codes simulate travel only by the K_d value of a given layer and not by species which could change as a function of time, approximations must be made. INTEG allows the user to assign K_d values by nuclide. Thus the user can choose to assign the value based on the initial nuclide in the chain or on its own value. Large differences can occur when parent and daughter have significantly different K_d values (for example, ^{237}Np and ^{233}U).

VI. AUXILIARY PROGRAM

PORCON

PORFLOW (ACri 1994) is one of the water flow and contaminant transport codes used in long-term performance assessment at Westinghouse Hanford. PORFLOW can only calculate results for 4 K_d values at a time. In order to provide greater flexibility in the number of K_d values and to make the vadose zone input file easier to read, a program entitled PORCON was written. PORCON reads a series of "fort.35" files produced by various PORFLOW and produces an output which has the contaminant flux density entering the aquifer. If the various PORFLOW runs have different time steps, then an union of time steps is used with the missing flux values obtained by linear interpolation.

The input file for PORCON is shown in Table 9. A sample file can be found in Appendix A, Section 9.

Table 9. Sample Input File for PORCON.

Line #	Input	Description
1	outfile	filename containing vadose zone information [a80]
2,4,...	infile	filename containing PORFLOW flux file (fort.35) [a80]
3,5,...	label	labels for each block [4(a8,2x)]

VII. REFERENCES

ACRi, 1994, *PORFLOW User's Manual*, Version 2.50, Analytic and Computational Research, Inc., Bel Air, California.

Kline, N. W., 1995, *Development of a Unit Cell Model for Interim Performance Assessment of Vitrified Low Level Waste Disposal*, WHC-SD-WM-RPT-189, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Rittmann, P. D., 1993, *GRTPA - A Program to Calculate Human Dose from PORFLOW OUTPUT*, WHC-SD-WM-18, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A Sample Files

1. Sample Input File

```

Mel Piepho base case for Interim Performance Assessment
wif 0.00177
recharge 3.0 mm/y
area 50000. m2
dwl 4.0 mrem/yr
dwl 4.0 mrem/yr
conral 3.0 pci/l
conal 15.0 pci/l
invfile inv.bac
t12f t12.bac
dwfile dw.bac
allfile all.bac
ntabf kd.bac
vadfile piepho.1-1d
end

```

2. Sample Inventory File

```

inv table 4-1 from WHC-SD-WM-RPT-200, Rev. 0
c 14 7.73E+0
se 79 1.03E+3
sr 90 1.61E+6
zr 93 4.87E+1
nb 93m 4.20E+1
tc 99 2.23E+4
sn126 1.58E+3
i 129 6.62E+0
cs137 4.51E+5
sm151 3.16E+4
ra226 2.35E-3
ra228 1.38E+0
ac227 1.08E+0
th229 9.79E-3
th232 2.68E-2
pa231 1.45E+2
u 233 2.58E+1
u 234 1.80E+1
u 235 7.36E-1
u 236 4.47E-1
u 238 1.78E+1
np237 3.74E+0
pu239 2.23E+3
pu240 4.31E+2
am241 4.25E+3
am243 2.70E+0
cm245 1.03E-1

```

3. Sample Half-life File

t12		Table 1.1 from WHC-SD-WM-TI-707, Rev. 0			
h	3	12.28	1.0	0.0	1.0
be	10	1.60E+06	1.0	0.0	1.0
c	14	5730.	1.0	0.0	1.0
na	22	2.602	1.0	0.0	1.0
cl	36	301000.	1.0	0.0	1.0
k	40	1.277E+09	1.0	0.0	1.0
mn	54	0.85613	1.0	0.0	1.0
fe	55	2.7	1.0	0.0	1.0
co	60	5.271	1.0	0.0	1.0
ni	59	75000.	1.0	0.0	1.0
ni	63	100.1	1.0	0.0	1.0
se	79	65000.	1.0	0.0	1.0
rb	87	4.73E+10	1.0	0.0	1.0
sr	90	28.6	1.0	0.0	1.0
zr	93	1.53E+06nb	1.0	0.0	1.0
nb	93m	14.6	1.0	0.0	1.0
nb	94	20300.	1.0	0.0	1.0
mo	93	3500.	1.0	0.0	1.0
tc	99	213000.	1.0	0.0	1.0
ru	106	1.0081	1.0	0.0	1.0
pd	107	6.50E+06	1.0	0.0	1.0
ag	108m	127.	1.0	0.0	1.0
cd	109	1.2704	1.0	0.0	1.0
cd	113m	13.7	1.0	0.0	1.0
in	115	4.6E+15	1.0	0.0	1.0
sn	121m	55.	1.0	0.0	1.0
sn	126	100000.	1.0	0.0	1.0
sb	125	2.77	1.0	0.0	1.0
i	129	1.57E+07	1.0	0.0	1.0
cs	134	2.062	1.0	0.0	1.0
cs	135	2.30E+06	1.0	0.0	1.0
cs	137	30.17	1.0	0.0	1.0
ba	133	10.5	1.0	0.0	1.0
pm	147	2.6234	1.0	0.0	1.0
sm	147	1.06E+11	1.0	0.0	1.0
sm	151	90.	1.0	0.0	1.0
eu	150	36.	1.0	0.0	1.0
eu	152	13.6	1.0	0.0	1.0
eu	154	8.8	1.0	0.0	1.0
eu	155	4.96	1.0	0.0	1.0
gd	152	1.10E+14	0.0	1.0	1.0
ho	166m	1200.	1.0	0.0	1.0
re	187	4.7E+10	1.0	0.0	1.0
tl	204	3.779	1.0	0.0	1.0
pb	210	22.26	0.0	1.0	1.0
bi	207	33.4	1.0	0.0	1.0
po	209	102.	1.0	0.0	1.0
ra	226	1600.pb210	1.0	1.0	2.0
ra	228	5.75th228	1.0	0.0	1.0
ac	227	21.773bi207	1.0	1.0	4.0
th	228	1.9132pb208	1.0	1.0	2.0
th	229	7340.po209	1.0	1.0	4.0
th	230	77000.ra226	0.0	1.0	0.0
th	232	1.405E+10ra228	0.0	1.0	0.0
pa	231	32764.ac227	0.0	1.0	0.0
u	232	7z.th228	0.0	1.0	0.0
u	233	159200.th229	0.0	1.0	0.0
u	234	244500.th230	0.0	1.0	0.0
u	235	7.038E+08pa231	1.0	1.0	1.0
u	236	2.34E+07u232	1.0	1.0	2.0
u	238	4.468E+09u234	1.0	1.0	2.0
np	237	2.14E+06u233	1.0	1.0	1.0
pu	236	2.851u232	0.0	1.0	0.0
pu	238	86.75u234	0.0	1.0	0.0
pu	239	24131.u235	0.0	1.0	0.0
pu	240	6569.u236	0.0	1.0	0.0
pu	241	14.4am241	1.0	0.0	1.0
pu	242	375800.u238	0.0	1.0	0.0
pu	244	8.26E+07pu240	1.0	1.0	2.0
am	242	432.2nc237	0.0	1.0	0.0
am	242m	152.pu238	1.0	1.0	1.0
am	243	7380.pu239	1.0	1.0	1.0
cm	243	28.5pu239	0.0	1.0	0.0
cm	244	18.11pu240	0.0	1.0	0.0
cm	245	8500.pu241	0.0	1.0	0.0

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cm246	4750.pu242	0.0	1.0	0.0	1.0	1.0
cm247	1.56E+07am243	1.0	1.0	1.0	1.0	1.0
cm248	339000.pu244	0.0	1.0	1.0	1.0	0.9174
chem-1	0.	1.0	0.0	1.0	0.0	1.0
chem-2	0.	1.0	0.0	1.0	0.0	1.0
chem-3	0.	1.0	0.0	1.0	0.0	1.0
chem-4	0.	1.0	0.0	1.0	0.0	1.0

4. Sample Vadose Zone File

VADOSE time(yrs)	kd=0.0	8 kd=0.0 x 380	kd=0.1	kd=0.6	kd=3.0	kd=15.	kd=40.	kd=100.
0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
6.89632E-02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
1.00000E+03	9.12916E-09	1.86744E-09	4.40591E-11	1.45131E-19	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
8.56026E+03	1.92511E-06	4.95169E-07	1.56339E-06	5.45478E-07	4.62944E-09	5.54757E-16	0.00000E+00	0.00000E+00
9.36026E+03	1.98391E-06	5.11210E-07	1.63806E-06	6.33264E-07	7.85433E-09	2.35347E-15	0.00000E+00	0.00000E+00
1.03017E+04	2.03892E-06	5.26373E-07	1.70755E-06	7.23700E-07	1.28194E-08	9.32620E-15	2.44033E-23	0.00000E+00
1.19017E+04	2.10064E-06	5.43594E-07	1.78570E-06	8.38786E-07	2.32138E-08	5.35688E-14	7.44455E-22	0.00000E+00
1.35017E+04	2.17411E-06	5.64398E-07	1.87105E-06	9.62988E-07	4.14517E-08	2.85840E-13	1.80175E-20	0.00000E+00
1.51017E+04	2.23933E-06	5.83166E-07	1.94297E-06	1.07464E-06	6.55343E-08	1.12660E-12	2.48109E-19	0.00000E+00
1.00000E+05	3.52839E-06	8.02000E-07	2.83533E-06	2.02320E-06	1.37228E-06	2.01934E-07	3.80694E-09	2.12243E-12

5. Sample Nuclide Block Identification File

Table 12-1 from WHC-SD-WM-Rpt-200, Rev. 0

vadlab		
h 3	kd=0.0	other
be 10	kd=0.0	other
c 14	kd=6.0	
na 22	kd=0.0	other
cl 36	kd=0.0	other
k 40	kd=0.0	other
mn 54	kd=0.0	other
fe 55	kd=0.0	other
co 60	kd=100.	
ni 59	kd=40.	
ni 63	kd=40.	
se 79	kd=0.0	
rb 87	kd=0.0	other
sr 90	kd=3.0	
zr 93	kd=40.	
nb 93m	kd=40.	
nb 94	kd=40.	
mo 93	kd=0.0	other
tc 99	kd=0.0	
ru106	kd=0.0	other
pd107	kd=0.0	other
ag108m	kd=0.0	other
cd109	kd=0.0	other
cd113m	kd=0.0	other
in115	kd=0.0	other
sn121m	kd=100.	
sn126	kd=100.	
sb125	kd=0.0	other
i 129	kd=3.0	
cs134	kd=100.	
cs135	kd=100.	
cs137	kd=100.	
ba133	kd=0.0	other
pm147	kd=0.0	other
sm147	kd=0.0	other
sm151	kd=0.0	other
eu150	kd=100.	
eu152	kd=100.	
eu154	kd=100.	
eu155	kd=100.	
gd152	kd=0.0	other
ho166m	kd=0.0	other
re187	kd=0.0	other
tl204	kd=0.0	other
pb210	kd=100.	
bi207	kd=0.0	other
po209	kd=0.0	other
ra226	kd=15.	
ra228	kd=15.	
ac227	kd=40.	
th228	kd=40.	
th229	kd=40.	
th230	kd=40.	
th232	kd=40.	
pa231	kd=6.0	
u 232	kd=0.6	
u 233	kd=0.6	
u 234	kd=0.6	
u 235	kd=0.6	
u 236	kd=0.6	
u 238	kd=0.6	
np237	kd=15.	
pu236	kd=40.	
pu238	kd=40.	
pu239	kd=40.	
pu240	kd=40.	
pu241	kd=40.	
pu242	kd=40.	
pu244	kd=40.	
am241	kd=40.	
am242m	kd=40.	
am243	kd=40.	
cm243	kd=100.	
cm244	kd=100.	
cm245	kd=100.	

cm246	kd=100.
cm247	kd=100.
cm248	kd=100.

6. Sample Drinking Water Dose Factor File

dw	mrem/y/pCi/l	Table 13-1 from WHC-SD-WM-RPT-200, Rev. 0
h 3	4.60E-05	
be 10	3.07E-03	
c 14	1.53E-03	
na 22	8.76E-03	
cl 36	2.19E-03	
k 40	1.39E-02	
mn 54	1.97E-03	
fe 55	4.23E-04	
co 60	1.90E-02	
ni 59	1.46E-04	
ni 63	3.94E-04	
se 79	6.06E-03	
rb 87	3.50E-03	
sr 90	1.02E-01	
zr 93	1.17E-03	
rb 93m	3.87E-04	
nb 94	3.72E-03	
mo 93	9.49E-04	
tc 99	9.49E-04	
ru106	1.53E-02	
pd107	1.02E-04	
ag108m	5.48E-03	
cd109	8.76E-03	
cd113m	1.10E-01	
in115	1.02E-01	
sn121m	1.45E-03	
sn126	1.34E-02	
sb125	2.51E-03	
i 129	2.04E-01	
cs134	5.40E-02	
cs135	5.18E-03	
cs137	3.65E-02	
ba133	2.34E-03	
pn147	6.94E-04	
sm147	1.31E-01	
sm151	2.48E-04	
eu150	4.53E-03	
eu152	4.38E-03	
eu154	6.64E-03	
eu155	9.49E-04	
gd152	1.10E-01	
ho166m	5.69E-03	
re187	6.06E-06	
tl204	2.34E-03	
pb210	4.92E+00	
bi207	3.58E-03	
po209	1.46E+00	
ra226	8.04E-01	
ra228	8.77E-01	
ac227	1.07E+01	
th228	5.50E-01	
th229	2.85E+00	
th230	3.87E-01	
th232	2.04E+00	
pa231	8.03E+00	
u 232	9.49E-01	
u 233	1.97E-01	
u 234	1.90E-01	
u 235	1.83E-01	
u 236	1.83E-01	
u 238	1.77E-01	
np237	2.85E+00	
pu236	9.49E-01	
pu238	2.77E+00	
pu239	3.14E+00	
pu240	3.14E+00	
pu241	6.28E-02	
pu242	2.99E+00	
pu244	2.92E+00	
am241	3.29E+00	
am242m	3.13E+00	
am243	3.29E+00	
cm243	2.12E+00	
cm244	1.68E+00	
cm245	3.29E+00	

cm246	3.29E+00
cm247	2.99E+00
cm248	1.17E+01
chem-1	0.0
chem-2	0.0
chem-3	0.0
chem-4	0.0

7. Sample All-Pathways Dose Factor File

allpath	mrem/y/pci/l	Table 13-2 from WHC-SD-RPT-200, Rev. 0
h 3	5.30E-05	
be 10	3.41E-03	
c 14	1.79E-03	
na 22	5.71E-02	
cl 36	3.40E-02	
k 40	3.06E-02	
mn 54	6.48E-03	
fe 55	6.57E-04	
co 60	4.84E-02	
ni 59	1.90E-04	
ni 63	5.13E-04	
se 79	1.09E-02	
rb 87	7.75E-03	
sr 90	1.26E-01	
zr 93	1.42E-03	
nb 93m	3.15E-03	
nb 94	4.12E-02	
mo 93	1.28E-03	
tc 99	3.12E-03	
ru106	1.85E-02	
pd107	1.99E-04	
ag108m	2.57E-02	
cd109	1.04E-02	
cd113m	1.30E-01	
in115	1.31E-01	
sn112m	4.28E-03	
sn126	5.29E-02	
sb125	5.52E-03	
i 129	4.13E-01	
cs134	1.22E-01	
cs135	1.09E-02	
cs137	8.02E-02	
ba133	4.93E-03	
pm147	8.31E-04	
sm147	1.58E-01	
sm151	2.98E-04	
eu150	1.54E-02	
eu152	1.28E-02	
eu154	1.61E-02	
eu155	1.36E-03	
gd152	1.28E-01	
ho166m	1.85E-02	
re187	8.56E-06	
tl204	4.95E-03	
pb210	5.50E+00	
bi207	1.44E-02	
po209	1.69E+00	
ra226	9.20E-01	
ra228	9.98E-01	
ac227	1.16E+01	
th228	6.08E-01	
th229	3.11E+00	
th230	4.22E-01	
th232	2.23E+00	
pa231	8.75E+00	
u 232	1.09E+00	
u 233	2.26E-01	
u 234	2.18E-01	
u 235	2.12E-01	
u 236	2.10E-01	
u 238	2.04E-01	
np237	3.11E+00	
pu236	1.03E+00	
pu238	3.02E+00	
pu239	3.42E+00	
pu240	3.42E+00	
pu241	6.84E-02	
pu242	3.26E+00	
pu244	3.18E+00	
am241	3.58E+00	
am242m	3.41E+00	
am243	3.58E+00	
cm243	2.31E+00	
cm244	1.83E+00	
cm245	3.58E+00	

cm246	3.58E+00
cm247	3.27E+00
cm248	1.27E+01
chem-1	0.0
chem-2	0.0
chem-3	0.0
chem-4	0.0

8. Sample Output

Program INTEG
Version 1.0
May 29, 1996
EDT 603224

Actions taken based on input

Mel Piepho base case

- 1) Well intercept factor set to 0.0018
- 2) recharge rate set to 1.000 mm/y
- 3) Area of disposal facility set to 50000.000 m²
- 4) Limit on drinking water dose set to 25.000 mrem/y
- 5) Limit on alpha drinking water dose set to 25.000 mrem/y
- 6) Limit on beta drinking water dose set to 25.000 mrem/y
- 7) Limit on radium concentrations set to 25.000 mrem/y
- 8) Limit on alpha concentrations set to 25.000 mrem/y
- 9) Inventory taken from file inv.bac

table 4-1 from WHC-SD-WM-RPT-200, Rev. 0

- 10) Half-lives taken from file t12.bac
Table 1.1 from WHC-SD-WM-TI-707, Rev. 0
- 11) Drinking water dose factors taken from file dw.bac
Table 13-1 from WHC-SD-WM-RPT-200, Rev. 0
- 12) All-pathways dose factors taken from file all.bac
Table 13-2 from WHC-SD-RPT-200, Rev. 0
- 13) Vadose zone labels for each nuclide take from file =kd.bac
Table 12-1 from WHC-SD-WM-Rpt-200, Rev. 0
- 14) Vadose zone file read in: piepho.1-1d
- 15) INPUT WARNING, geometric factor reset to 1

Data Used in Calculation

Mel Piepho base case

Inventory

based on data on file = inv.bac

Half-Life

based on data on file = t12.bac

Vadose Zone

based on data on file = piepho.1-1d

kd labels

based on data on file = kd.bac

Dose Factors - all pathways

based on data on file = all.bac

Dose Factors - drinking water

based on data on file = dw.bac

General Data

recharge 1.0000E+00 mm/y
area of disposal facility 5.0000E+04 m**2
well intercept factor 1.7700E-03

Aquifer Transport Time

No credit taken for aquifer travel time

nuclide	amount (Ci)	half-life (year)	daughter	kd-label	all-path df (mrem/year per Ci/L)	dw df	beta	alpha	br
c 14	7.7300E+00	5.7300E+03		kd=3.0	1.7900E+09	1.5300E+09	1.0	0.0	1.0
se 79	1.0300E+03	6.5000E+04		kd=0.0	1.0900E+10	6.0600E+09	1.0	0.0	1.0
sr 90	1.6100E+06	2.8600E+01		kd=3.0	1.2600E+11	1.0200E+11	1.0	0.0	1.0
zr 93	4.8700E+01	1.5300E+06		kd=40.	1.4200E+09	1.1700E+09	1.0	0.0	1.0
nb 93m	4.2000E+01	1.4600E+01	nb 93m	kd=40.	3.1500E+09	3.8700E+08	1.0	0.0	1.0
tc 99	2.2300E+04	2.1300E+05		kd=0.0	3.1200E+09	9.4900E+08	1.0	0.0	1.0
sn126	1.5800E+03	1.0000E+05		kd=100.	5.2900E+10	1.3400E+10	1.0	0.0	1.0
i 129	6.6200E+00	1.5700E+07		kd=3.0	4.1300E+11	2.0400E+11	1.0	0.0	1.0
cs137	4.5100E+05	3.0170E+01		kd=100.	8.0200E+10	3.6500E+10	1.0	0.0	1.0
sm151	3.1600E+04	9.0000E+01		kd=0.0	2.9800E+08	2.4800E+08	1.0	0.0	1.0
pb210	0.0000E+00	2.2260E+01		kd=100.	5.5000E+12	4.9200E+12	1.0	1.0	2.0
bf207	0.0000E+00	3.3400E+01		kd=0.0	1.4400E+10	3.5800E+09	1.0	0.0	1.0
po209	0.0000E+00	1.0200E+02		kd=0.0	1.6900E+12	1.4600E+12	0.0	1.0	0.0

ra226	2.3500E-03	1.6000E+03	pb210	kd=15.	9.2000E+11	8.0400E+11	1.0	1.0	2.0	4.0	1.000
ra228	1.3800E+00	5.7500E+00	th228	kd=15.	9.9800E+11	8.7700E+11	1.0	0.0	2.0	0.0	1.000
ac227	1.0800E+00	2.1773E+01	bi207	kd=40.	1.1600E+13	1.0700E+13	1.0	1.0	3.0	5.0	1.000
th228	0.0000E+00	1.9132E+00		kd=40.	6.0800E+11	5.5000E+11	1.0	1.0	2.0	5.0	1.000
th229	9.7900E-03	7.3400E+03	pc209	kd=40.	3.1100E+12	2.8500E+12	1.0	1.0	3.0	5.0	1.000
th230	0.0000E+00	7.7000E+04	ra226	kd=40.	4.2200E+11	3.8700E+11	0.0	1.0	0.0	1.0	1.000
pa231	1.4500E-02	1.4050E+10	ra228	kd=40.	2.2300E+12	2.0400E+12	0.0	1.0	0.0	1.0	1.000
u 232	0.0000E+00	7.2000E+01	ac227	kd=3.0	8.7500E+12	8.0300E+12	0.0	1.0	0.0	1.0	1.000
u 233	2.5800E+01	1.5920E+05	th229	kd=0.6	1.0900E+12	9.4900E+11	0.0	1.0	0.0	1.0	1.000
u 234	1.8000E+01	2.4450E+05	th230	kd=0.6	2.2600E+11	1.9700E+11	0.0	1.0	0.0	1.0	1.000
u 235	7.3600E-01	7.0380E+08	pa231	kd=0.6	2.1800E+11	1.9000E+11	0.0	1.0	0.0	1.0	1.000
u 236	4.4700E-01	2.3400E+07	u 232	kd=0.6	2.1200E+11	1.8300E+11	1.0	1.0	1.0	1.0	1.000
u 238	1.7800E+01	4.4680E+09	u 233	kd=0.6	2.1000E+11	1.8300E+11	1.0	1.0	2.0	1.0	1.000
np237	3.7400E+00	2.1400E+06	u 234	kd=0.6	2.0400E+11	1.7700E+11	1.0	1.0	2.0	1.0	1.000
pu239	2.2300E+03	2.4131E+04	u 235	kd=15.	3.1100E+12	2.8500E+12	1.0	1.0	1.0	1.0	1.000
pu240	4.3100E+02	6.5690E+03	u 236	kd=40.	3.4200E+12	3.1400E+12	0.0	1.0	0.0	1.0	1.000
pu241	0.0000E+00	1.4400E+01	am241	kd=40.	3.4200E+12	3.1400E+12	0.0	1.0	0.0	1.0	1.000
am241	4.2500E+03	4.3220E+02	np237	kd=40.	6.8400E+10	6.2800E+10	1.0	0.0	1.0	0.0	1.000
am243	2.7000E+00	7.3800E+03	pu239	kd=40.	3.5800E+12	3.2900E+12	1.0	1.0	1.0	1.0	1.000
cm245	1.0300E-01	8.5000E+03	pu241	kd=100.	3.5800E+12	3.2900E+12	0.0	1.0	0.0	1.0	1.000

	max year	max		limit	year
beta/photon dose	71102.	2.737	mrem/yr	4.000	mrem/yr
alpha dose	50302.	17.417	mrem/yr	4.000	mrem/yr
drinking water dose	50302.	19.862	mrem/yr	4.000	mrem/yr
all-pathways dose	50302.	26.668	mrem/yr	25.000	mrem/yr
total concentration	66302.	2205.311	pCi/l		
alpha concentration	58302.	8.175	pCi/l	15.000	pCi/l
radium concen.	100000.	0.075	pCi/l	3.000	pCi/l
uranium concen	71102.	4.098	pCi/l		

Otime	beta dose	alpha dose	drinking water dose	all-pathway dose
(years)	(mrem/yr)	(mrem/yr)	(mrem/yr)	(mrem/yr)
.	.	.	.	.
.	.	.	.	.
1000.	0.009	0.001	0.010	0.028
.	.	.	.	.
.	.	.	.	.
4560.	1.399	0.703	2.087	4.932
5360.	1.514	0.885	2.376	5.462
6160.	1.636	1.092	2.695	6.037
6960.	1.735	1.307	2.999	6.550
7760.	1.817	1.534	3.297	7.022
8560.	1.886	1.779	3.600	7.476
9360.	1.945	2.048	3.917	7.925
10302.	1.998	2.380	4.292	8.429
11902.	2.055	2.939	4.893	9.184
13502.	2.122	3.720	5.727	10.213
15102.	2.180	4.614	6.666	11.339
16702.	2.230	5.594	7.683	12.537
18302.	2.274	6.627	8.750	13.777
19902.	2.313	7.685	9.837	15.031
.	.	.	.	.
.	.	.	.	.
100000.	2.679	11.574	13.825	19.820

Otime	drinking water doses			
(years)	Tc	Se	U	Np
	(mrem/yr)	(mrem/yr)	(mrem/yr)	(mrem/yr)
.	.	.	.	.
.	.	.	.	.
1000.	0.007	0.002	0.000	0.000
.	.	.	.	.
.	.	.	.	.
4560.	1.058	0.302	0.055	0.000
5360.	1.142	0.324	0.084	0.000
6160.	1.230	0.346	0.119	0.000
6960.	1.300	0.364	0.158	0.000
7760.	1.356	0.378	0.197	0.000

WHC-SD-WM-RPT-219, Rev. 0

8560.	1.403	0.388	0.236	0.000
9360.	1.442	0.397	0.274	0.000
10302.	1.477	0.404	0.313	0.000
11902.	1.514	0.409	0.362	0.000
13502.	1.559	0.416	0.415	0.000
15102.	1.597	0.421	0.462	0.000
16702.	1.630	0.425	0.504	0.000
18302.	1.660	0.427	0.541	0.000
19902.	1.686	0.429	0.573	0.000
.	.	.	.	.
.	.	.	.	.
100000.	1.909	0.268	0.784	0.091

Otime	Radionuclide Concentrations			
(years)	Sum	alpha	Ra	U
	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)
.	.	.	.	.
.	.	.	.	.
1000.	7.564	0.001	0.000	0.000
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
4560.	1172.579	0.726	0.000	0.283
5360.	1264.950	0.975	0.000	0.429
6160.	1361.994	1.269	0.000	0.612
6960.	1439.428	1.571	0.000	0.807
7760.	1501.840	1.876	0.000	1.009
8560.	1553.206	2.177	0.000	1.209
9360.	1596.305	2.469	0.000	1.402
10302.	1635.290	2.778	0.000	1.600
11902.	1675.479	3.199	0.000	1.851
13502.	1724.519	3.664	0.000	2.121
15102.	1766.430	4.104	0.000	2.362
16702.	1802.441	4.519	0.000	2.576
18302.	1834.131	4.905	0.000	2.764
19902.	1862.631	5.262	0.000	2.927
.	.	.	.	.
.	.	.	.	.
100000.	2069.086	7.637	0.075	4.009

9. Sample Fort.7 File

1000.	se 79	1.0191E+03	3.2934E-13	0.002	0.002	0.000	0.004
1000.	tc 99	2.2228E+04	7.1833E-12	0.007	0.007	0.000	0.022
1000.	sm151	1.4286E+01	4.6168E-15	0.000	0.000	0.000	0.000
1000.	bi207	1.4222E+02	4.5961E-14	0.000	0.000	0.000	0.001
1000.	po209	2.0003E+00	6.4643E-16	0.001	0.000	0.001	0.001
.	.	.	.	.	.	.	.
10302.	c 14	2.2232E+00	1.0089E-15	0.000	0.000	0.000	0.000
10302.	se 79	9.2284E+02	6.6609E-11	0.404	0.404	0.000	0.726
10302.	tc 99	2.1565E+04	1.5565E-09	1.477	1.477	0.000	4.856
10302.	i 129	6.6170E+00	3.0028E-15	0.001	0.001	0.000	0.001
10302.	bi207	1.1695E+02	8.4410E-12	0.030	0.030	0.000	0.122
10302.	po209	1.5583E+01	1.1247E-12	1.642	0.000	1.642	1.901
10302.	pa231	1.1675E+02	5.2983E-14	0.425	0.000	0.425	0.464
10302.	u 232	5.2659E-01	1.3491E-14	0.013	0.000	0.013	0.015
10302.	u 233	2.4867E+01	6.3708E-13	0.126	0.000	0.126	0.144
10302.	u 234	1.7994E+01	4.6099E-13	0.088	0.000	0.088	0.100
10302.	u 235	7.5558E-01	1.9357E-14	0.004	0.004	0.004	0.004
10302.	u 236	5.2704E-01	1.3502E-14	0.002	0.002	0.002	0.003
10302.	u 238	1.7800E+01	4.5602E-13	0.081	0.081	0.081	0.093
.	.	.	.	.	.	.	.
100000.	c 14	4.3112E-05	2.0943E-18	0.000	0.000	0.000	0.000
100000.	se 79	3.5458E+02	4.4289E-11	0.268	0.268	0.000	0.483
100000.	zr 93	4.6543E+01	6.2724E-15	0.000	0.000	0.000	0.000
100000.	nb 93m	4.6543E+01	6.2725E-15	0.000	0.000	0.000	0.000
100000.	tc 99	1.6106E+04	2.0117E-09	1.909	1.909	0.000	6.276
100000.	sn126	7.9000E+02	5.9356E-17	0.000	0.000	0.000	0.000
100000.	i 129	6.5908E+00	3.2017E-13	0.065	0.065	0.000	0.132
100000.	bi207	1.8212E+01	2.2748E-12	0.008	0.008	0.000	0.033
100000.	po209	1.8962E+01	2.3684E-12	3.458	0.000	3.458	4.003
100000.	ra226	1.0511E+01	7.5138E-14	0.060	0.060	0.060	0.069
100000.	ra228	2.6800E-02	1.9158E-16	0.000	0.000	0.000	0.000
100000.	ac227	1.8194E+01	2.4519E-15	0.026	0.026	0.026	0.028
100000.	th228	5.9315E-01	7.9936E-17	0.000	0.000	0.000	0.000
100000.	th229	1.8953E+01	2.5542E-15	0.007	0.007	0.007	0.008
100000.	th230	1.0666E+01	1.4374E-15	0.001	0.000	0.001	0.001
100000.	th232	2.6800E-02	3.6117E-18	0.000	0.000	0.000	0.000
100000.	pa231	1.8183E+01	8.8329E-13	7.093	0.000	7.093	7.729
100000.	u 232	5.6635E-01	4.0562E-14	0.038	0.000	0.038	0.044
100000.	u 233	1.8287E+01	1.3097E-12	0.258	0.000	0.258	0.296
100000.	u 234	1.7951E+01	1.2856E-12	0.244	0.000	0.244	0.280
100000.	u 235	8.0808E-01	5.7876E-14	0.011	0.011	0.011	0.012
100000.	u 236	5.6634E-01	4.0562E-14	0.007	0.007	0.007	0.009
100000.	u 238	1.7800E+01	1.2748E-12	0.226	0.226	0.226	0.260
100000.	np237	4.4524E+00	3.1827E-14	0.091	0.091	0.091	0.099
100000.	pu239	1.2620E+02	1.7007E-14	0.053	0.000	0.053	0.058
100000.	pu240	1.1269E-02	1.5187E-18	0.000	0.000	0.000	0.000

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