

SECTION 7.0

EUROPIUM

7.0 EUROPIUM

This section provides technical information on the sources, characteristics, biokinetics, and dosimetry of ^{154}Eu and ^{155}Eu --the principal europium radionuclides of concern from an internal exposure standpoint at Hanford.

7.1 SOURCES AND CHARACTERISTICS OF EUROPIUM

Europium-154 ($T_{1/2} = 8.8$ yr) and ^{155}Eu ($T_{1/2} = 4.96$ yr) have been produced historically at Hanford by the N Reactor through neutron activation of samarium oxide marbles used in the reactor's safety system. The samarium-oxide marbles were replaced in 1978 with marbles made of boron carbide; however, a few of the old samarium-oxide marbles remained lodged in the graphite block moderator and continued to be activated during operation of the reactor until its shutdown in 1986.

The principal locations where exposures to europium radionuclides may occur are the 100-N Area and the waste management facilities in the 200 Areas where contaminated waste from N Reactor is handled.

7.2 BIOKINETIC BEHAVIOR OF EUROPIUM

ICRP 30 (1979) recommends that all compounds of europium (including nitrates, chlorides, and oxides) be assigned to inhalation class W. Experience at Hanford suggests that europium oxide may occasionally be more tenaciously retained in the lung than would be expected for a class W material. However, at this time data are insufficient to establish a case for class Y europium at Hanford.

Based on numerous measurements made at various N Reactor locations (Weetman and DeHaven 1982a) a particle size of $0.5 \mu\text{m}$ AMAD should be assumed, unless specific particle size data are available. According to the Task Group on Lung Dynamics (TGLD 1966) model of the respiratory tract, an inhaled aerosol, lognormally distributed with an AMAD of $0.5 \mu\text{m}$, will be deposited as follows: 16% in the nasal-passage (N-P) region of the respiratory tract, 8% in the tracheal-bronchial (T-B) region of the lung, and 33% in the pulmonary (P) region of the lung (see Appendix D).

According to ICRP 30, europium that enters the bloodstream is deposited and tenaciously retained in the liver and on bone surfaces. The distribution of europium entering the blood is given by ICRP 30 as follows:

- liver--40% ($T_{1/2} = 3500$ days)
- bone--40% surfaces ($T_{1/2} = 3500$ days)
- kidney--6% ($T_{1/2} = 10$ days)
- unabsorbed and excreted directly--14%.

7.3 INTERNAL DOSIMETRY FOR EUROPIUM

Using the computer code GENMOD (Johnson and Carver 1981; see Appendix A), an evaluation of the resulting internal organ doses following an intake of europium shows that the dose incurred by the kidney is negligible with respect to the liver and bone surface doses and does not contribute to the effective dose equivalent. Also, because of the short retention time in the kidney, europium observed in the body (excluding the lung) can be assumed to be distributed evenly between the liver and the bone surfaces.

Because of the long retention time for europium in the bone and liver, internal dose may accumulate for years following an intake. In most exposure cases (either class W or class Y), the lung can be expected to be the primary contributor to the effective dose equivalent during the first year following an intake. For the more soluble forms of europium (class W), the liver eventually becomes the principal contributor to effective dose equivalent. Table 7.1 gives first-year and the 50-year committed dose equivalent per nano-curie of inhalation intake of ^{154}Eu and ^{155}Eu , assuming the physical and biokinetic characteristics discussed previously. Table 7.2 shows the time over which the internal dose from an inhalation intake of ^{154}Eu or ^{155}Eu is accumulated.

Figures 7.1 through 7.4 show the activity of ^{154}Eu and ^{155}Eu in the total body, the lung, and the bones or liver following an acute inhalation resulting in a first-year effective dose equivalent of 10 mrem. From the graphs, it is apparent that from about 6 months to 2 years after intake the total body activities for class W and class Y compounds are of roughly similar magnitude.

TABLE 7.1. First-Year and Committed Dose Equivalent Following an Acute Inhalation Intake of 1 nCi of ^{154}Eu or ^{155}Eu (a)

	Dose Equivalent, mrem/nCi Intake			
	^{154}Eu		^{155}Eu	
	Class W	Class Y	Class W	Class Y
Effective Dose Equivalent				
1st-year	0.073	0.15	0.013	0.026
50-year	0.30	0.55	0.044	0.080
Lung				
1st-year	0.29	1.1	0.054	0.20
50-year	0.36	3.4	0.057	0.54
Bone Surface				
1st-year	0.24	0.029	0.096	0.0078
50-year	2.0	0.79	0.57	0.19
Bone Marrow				
1st-year	0.053	0.019	0.0095	0.0024
50-year	0.40	0.20	0.054	0.022
Kidney				
1st-year	0.024	0.014	0.0022	0.00071
50-year	0.13	0.087	0.0064	0.0035
Liver				
1st-year	0.20	0.042	0.031	0.0039
50-year	1.6	0.71	0.18	0.063

(a) Acute inhalation of 0.5- μm -AMAD aerosol.

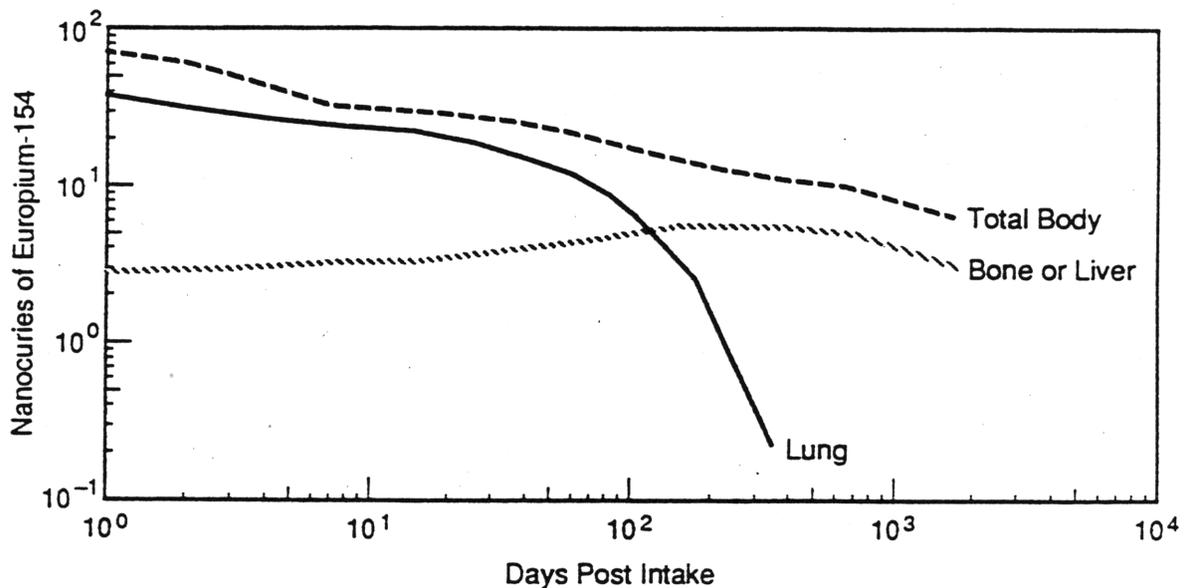
Table 7.3 shows fractional retention values for selected days post intake. Retention fractions for other organs or times post intake can be obtained using the GENMOD Code.

The ALI for class W ^{154}Eu is 20 μCi . The stochastic ALI for class W ^{155}Eu is 140 μCi , and the nonstochastic ALI for class W ^{155}Eu is 80 μCi , based on dose to bone surfaces.

TABLE 7.2. Accumulation of Effective Dose Equivalent Following an Acute Inhalation of Europium^(a)

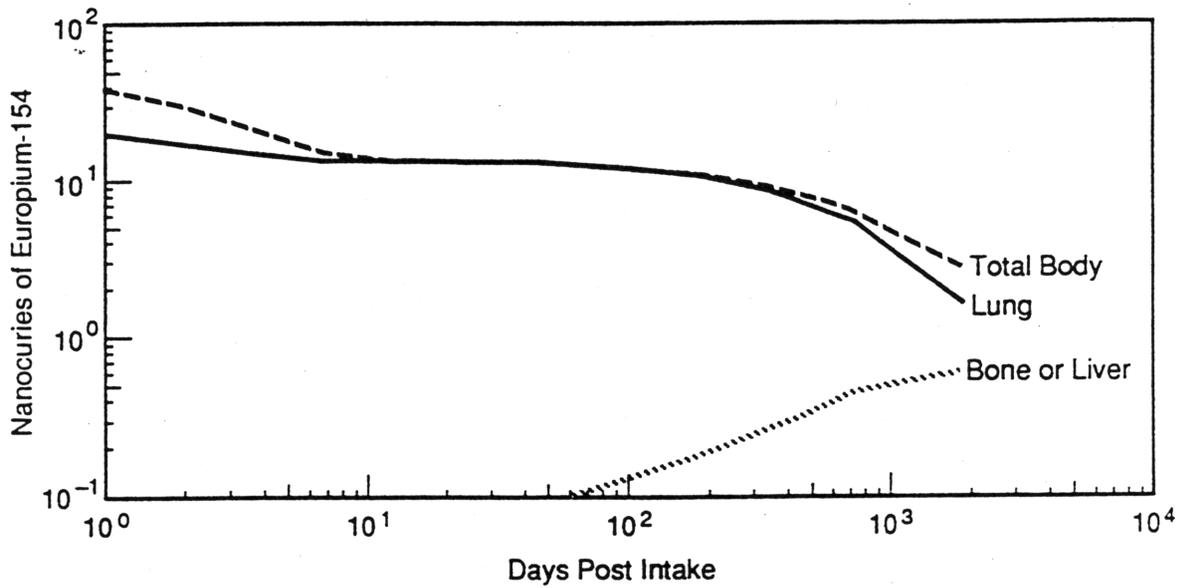
Years Post Intake	Percent of 50-Year Committed Effective Dose Equivalent Received			
	¹⁵⁴ Eu		¹⁵⁵ Eu	
	Class W	Class Y	Class W	Class Y
1	24	26	30	32
2	35	44	44	52
5	59	71	70	80
10	81	87	89	94
20	96	96	98	99
50	100	100	100	100

(a) Acute inhalation of 0.5- μ m-AMAD aerosol.



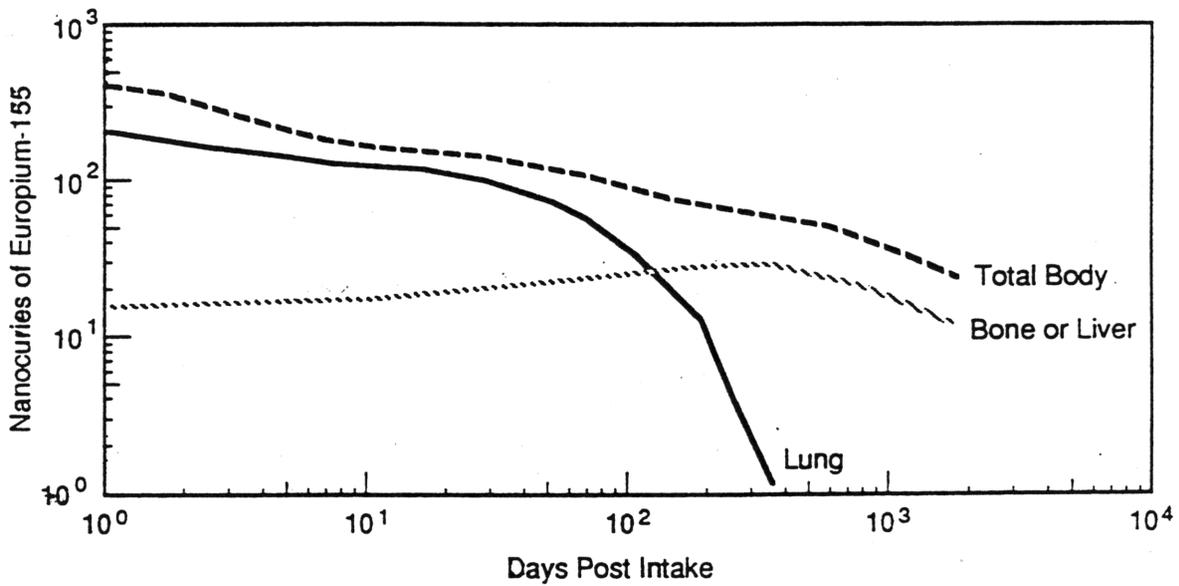
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FIGURE 7.1. ¹⁵⁴Eu in the Body Following an Inhalation Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem, Class W



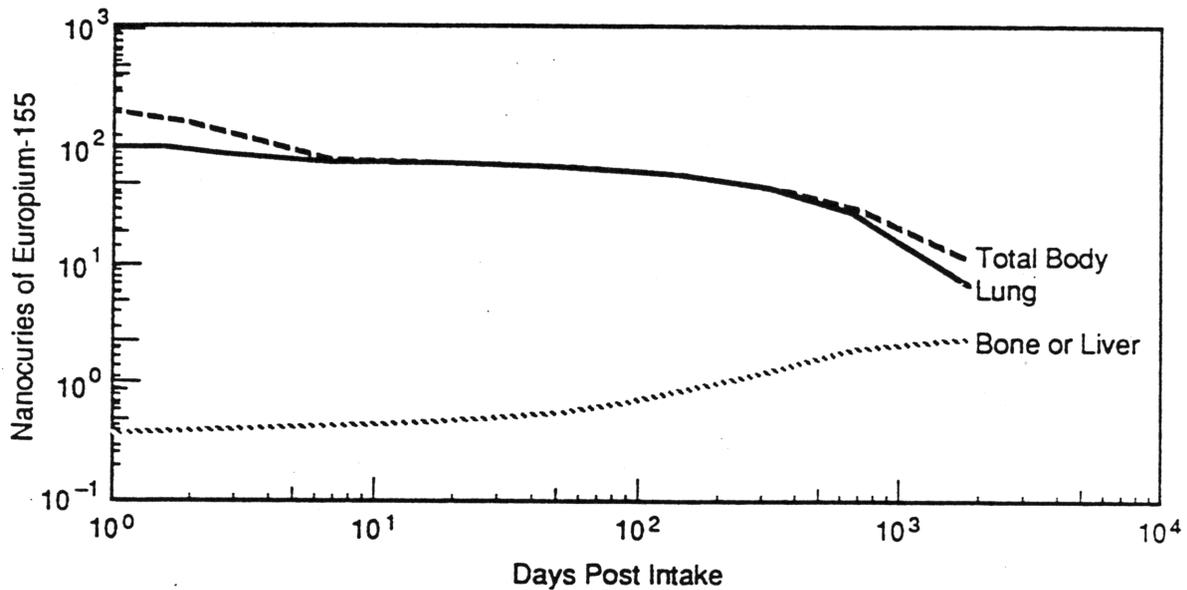
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FIGURE 7.2. ^{154}Eu in the Body Following an Inhalation Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem, Class Y



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FIGURE 7.3. ^{154}Eu in the Body Following an Inhalation Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem, Class W



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FIGURE 7.4. ^{155}Eu in the Body Following an Inhalation Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem, Class Y

7.4 BIOASSAY

In vivo measurements and excreta analysis and their use in a routine bioassay monitoring program and following an acute intake are discussed in the following subsections.

7.4.1 Bioassay Measurements

Both ^{154}Eu and ^{155}Eu are readily measured by in vivo bioassay techniques.

In Vivo Measurements

Europium-154 is the predominant long-lived europium radioisotope in europium isotope mixtures at Hanford. During the operating lifetime of N Reactor, the $^{154}\text{Eu}/^{155}\text{Eu}$ activity ratio has generally been about 2.0. This ratio will increase now that europium is no longer produced due to the longer half-life of ^{154}Eu . Because ^{154}Eu is also more easily detectable in vivo than ^{155}Eu , it is the best indicator of an intake of europium radionuclides.

TABLE 7.3. Total Body Retention Following an Acute Inhalation Exposure to 0.5- μm AMAD Particles (expressed as fraction of intake)

Days Post Intake	^{154}Eu		^{155}Eu	
	Class W	Class Y	Class W	Class Y
0	5.70E-1	5.70E-1	5.70E-1	5.70E-1
1	5.35E-1	5.34E-1	5.35E-1	5.34E-1
2	4.42E-1	4.21E-1	4.42E-1	4.21E-1
5	2.70E-1	2.32E-1	2.70E-1	2.32E-1
7	2.43E-1	2.07E-1	2.43E-1	2.07E-1
14	2.22E-1	1.98E-1	2.22E-1	1.97E-1
30	1.96E-1	1.94E-1	1.95E-1	1.93E-1
60	1.62E-1	1.87E-1	1.60E-1	1.85E-1
90	1.38E-1	1.81E-1	1.36E-1	1.78E-1
180	1.04E-1	1.64E-1	1.01E-1	1.59E-1
365	8.58E-2	1.35E-1	8.09E-2	1.27E-1
730	7.27E-2	9.49E-2	6.47E-2	8.44E-2
1,825	4.58E-2	4.34E-2	3.43E-2	3.24E-2
3,650	2.12E-2	1.85E-2	1.19E-2	1.03E-2
7,300	4.56E-3	4.46E-3	1.42E-3	1.39E-3
18,250	4.55E-5	1.19E-4	2.57E-6	6.48E-6

Europium-155 is more difficult to detect in vivo because its predominant gamma emission falls in the low-energy noise region of the standard whole body count.

Whole body counting for ^{154}Eu is conveniently performed using the 5-NaI-detector preview counter (Palmer et al. 1990). The standard 3-minute count performed using the system will detect the presence of 4.5 nCi in the total body or about 3.4 nCi in the chest region. The preview counter provides a quantitative indication of the presence of radioactivity in the body. Nevertheless, it is routine practice to establish internal deposition

quantities for radionuclides detected with the preview counter by using the high-resolution large-volume coaxial germanium detector system described by Palmer et al. (1990).

Total body content of ^{155}Eu cannot be directly measured with the Hanford whole body counter. It can be estimated by establishing a ^{155}Eu -to- ^{154}Eu ratio using chest or skeleton counts and then applying that ratio to the ^{154}Eu whole body count result. Skeleton counting would provide more sensitive ratio for ^{155}Eu estimation.

Special measurements of lung, skeleton, or liver content may be desired to establish individual-specific patterns of distribution and retention. Because europium is a bone-seeking radionuclide, chest counts performed more than several weeks after intake may be detecting activity in the bones of the chest, as well as in the lung. Therefore, any quantification of lung activity should consider the contribution from the bones.

Skeleton activity is estimated from a head count. A correction factor can then be derived for obtaining lung activity from a chest count. These calculations are performed by the PNL Whole Body Counter (WBC) group.

Table 7.4 summarizes in vivo detection capabilities.

TABLE 7.4. Detection Levels for In Vivo Measurements for ^{154}Eu and ^{155}Eu (a), nCi

<u>Count Type</u>	<u>Organ/Tissue</u>	<u>^{154}Eu</u>	<u>^{155}Eu</u>	<u>Length of Count, s</u>
Preview	Whole body	4.5	NA	200
Coaxial germanium	Chest	3.4	NA	1200
Chest	Lung	0.07	0.18	2000
Skull	Skeleton	0.22	0.37	3000

(a) From Palmer et al. (1990). (See also Appendix C.)

(b) NA = not applicable.

Excreta Analysis

Europium intakes can be detected and assessed through collection and analysis of urine and fecal samples. However, because in vivo measurements provide a direct and sensitive method for assessing internal depositions of europium radionuclides, excreta measurements are generally not necessary.

7.4.2 Routine Bioassay Monitoring Program

Routine bioassay monitoring for ^{154}Eu and ^{155}Eu is accomplished by in vivo measurements, principally for ^{154}Eu because of its predominance in europium mixtures and its easy detectability. Table 7.5 shows the activity of ^{154}Eu and ^{155}Eu in the body at various times after acute inhalation intake of a quantity that would result in a first-year effective dose equivalent of 10 mrem.

From Table 7.5, it is evident that an annual in vivo measurement frequency using the preview counter (MDA = 4.5 nCi for ^{154}Eu) is sufficient to

TABLE 7.5. Expected Whole Body Count Quantities Following an Inhalation Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem^(a,b)

Days Post Intake	Activity in the Total Body, nCi			
	^{154}Eu		^{155}Eu	
	Class W	Class Y	Class W	Class Y
7	29	14	180	80
14	27	14	165	76
30	27	13	145	75
60	26	13	119	72
90	25	12	101	69
180	23	11	75	62
365	19	9.3	60	49
730	13	6.5	48	33

(a) The expected total body activity values were calculated assuming a 0.5- μm -AMAD particle size.

(b) ^{154}Eu Intake = 140 nCi (class W) or 69 nCi (class Y)
 ^{155}Eu Intake = 740 nCi (class W) or 390 nCi (class Y).

detect an intake of ^{154}Eu at a 10-mrem first-year effective dose equivalent. A supplemental skeleton count to establish the ^{155}Eu -to- ^{154}Eu ratio would allow determination of the total body content of ^{155}Eu also at a level corresponding to a 10-mrem first-year effective dose equivalent. The first-year effective dose implied by an MDA ^{155}Eu measurement of $4.5 \mu\text{Ci}$ and an MDA skeleton count is 6.4 mrem for the combined isotopes of ^{154}Eu and ^{155}Eu . An annual in vivo measurement frequency would also be capable of detecting a 50-year committed effective dose equivalent of 100 mrem, as can be determined using the ratios of first-year to 50-year effective dose equivalents from Table 7.1.

Routine measurements in which a europium radionuclide is detected should be confirmed by follow-up in vivo measurements. The recommended protocol is to use high-resolution germanium detector whole body counting to confirm the identity and magnitude of the activity indicated by the preview counter. Because of the adequate sensitivity of whole body counting, supplemental chest and skeleton measurements are not generally warranted for intake or dose assessment unless unusual retention or distribution is suspected.

7.4.3 Bioassay Measurements Following An Acute Intake

An in vivo whole body examination should be performed following a suspected intake. However, unless the exposure appears to be of such magnitude that actions to hasten the removal of the material from the body are considered, the initial examination can be at the earliest convenient time during normal working hours. A measurement of the chest or skeleton is warranted to establish the ^{155}Eu -to- ^{154}Eu ratio.

Because there is much movement of inhaled material in the body during the first hours following an inhalation intake, early in vivo measurements should be considered semiquantitative. Measurements to determine total body retention for dose assessment purposes should not be performed until after about 5 days to allow for the early elimination of material via the GI tract. Likewise specialized measurements to estimate clearance rates from specific organs (i.e., chest counts and skeleton counts) should also be delayed until early GI tract clearance is complete.

7.5 ASSESSMENT OF INTERNAL DOSE

Europium radionuclides of concern can be readily detected and quantified by in vivo measurements. Several methods exist to evaluate in vivo measurement results in order to assess internal dose equivalent. The simplest method, and one that is recommended for initial evaluation of in vivo results as well as for final evaluations when annual effective doses are 100 mrem or less, involves fitting the expected internal activity using the biokinetic model prescribed in this section to whole body measurement data. This model is implemented using GENMOD (see Appendix A), and Table 7.3 and Figures 7.1 through 7.4 provide the expected retention values after an intake.

Assumptions used for this simplified evaluation are that the material is inhaled in class W or Y form, that the intake date, if unknown, is assumed to be the midpoint of the period during which the intake could have occurred, and that the inhaled aerosol had an AMAD of $0.5 \mu\text{m}$. The expected retention values per unit of intake are fit to the observed data using methods described in Appendix C to determine the intake. Intake dose equivalent factors, such as those in Table 7.1, may then be applied to compute dose equivalent.

If it is determined that the intake could potentially result in an annual effective dose equivalent in excess of 100 mrem, then an investigation should be performed to determine whether other radionuclides were involved, to review the validity of the above-stated assumptions, and to develop specific retention functions for the lung and body.

The objective of bioassay measurements performed for the purpose of assessing the internal dose based on observed retention and distribution is to establish, on a calendar-year basis, the integrated activity (in nCi-days) for the lung, the bone, and the liver. Because the bones of the chest interfere with the assessment of the pulmonary retained quantity, a combination chest and head count is advisable for estimating the true activity in the lung. The activity in the rest of the body can be estimated from a whole body count with subtraction of the true lung activity, or by direct counting of the skeleton and the liver.

Retention observed in vivo can be graphically analyzed to determine the cumulative activity by integrating under the observed retention curve. Once the annual integrated activity (in nCi-days) is established, the DCFs in Table 7.6 can be applied to derive the organ and effective dose equivalent. The internal effective dose equivalent is the sum of the effective dose equivalent contribution from activity in the lung and the effective dose equivalent contribution from activity in the bone plus liver.

Dose assessments include annual and committed effective dose equivalents, as well as dose equivalents to specific organs of concern based on the criteria presented in the Hanford Internal Dosimetry Program Manual.^(a) (See also Appendix B). Dose factors for organs receiving the greatest dose equivalent are provided in Tables 7.1 and 7.5.

7.6 MANAGEMENT OF INTERNAL CONTAMINATION CASES

Although, historically, there have been internal exposure cases involving europium radionuclides at Hanford, in no case have the exposures resulted in significant internal doses relative to occupational exposure limits. Because europium radionuclides are no longer produced, the concentrations of europium radionuclides at Hanford are slowly diminishing.

In vivo measurements performed following a potential intake provide an initial indication of the significance of an intake, although external contamination and rapid translocation of the material through the body may interfere with the accuracy of the measurement. If a significant intake is indicated, then various mitigative actions are possible. Purgatives or laxatives, as well as enemas or colonic irrigations, may reduce the residence time of the radionuclide in the GI tract, thereby reducing absorption by the blood (NCRP 1980). Once absorbed, diethylene triamine penta acetate (DTPA) may be considered (NCRP 1980). Hanford Environmental Health Foundation Occupational Medicine should be notified immediately upon indication of a severe intake potentially requiring mitigative action.

(a) Pacific Northwest Laboratory. 1989. Hanford Internal Dosimetry Program Manual. PNL-MA-552, Richland, Washington.

TABLE 7.6. Dose Conversion Factors for Radioisotopes of Europium^(a)

<u>Site of Deposition</u>	<u>Target Organ</u>	<u>DCF, rem/nCi-day in Source Organ</u>	
		<u>¹⁵⁴Eu</u>	<u>¹⁵⁵Eu</u>
Lungs	Lungs	1.8E-5	3.4E-6
	Effective	2.1E-6	4.1E-7
Body ^(b)	Bone surface	8.2E-6	3.3E-6
	Bone marrow	1.6E-6	3.1E-7
	Liver	6.6E-6	1.1E-6
	Effective	1.3E-6	2.2E-7
Bone surface ^(c)	Bone surface	1.7E-5	6.7E-6
	Bone marrow	5.6E-6	1.2E-6
	Liver	1.5E-7	7.6E-9
	Effective	7.3E-7	2.5E-7
Liver ^(c)	Bone surface	1.6E-7	1.8E-8
	Bone marrow	2.2E-7	1.7E-8
	Liver	1.3E-5	2.2E-6
	Effective	8.0E-7	1.3E-7

(a) Based on SEE factors in ICRP 30.

(b) Excludes lung and assumes 50% in liver and 50% on bone surfaces. Organs shown contribute 10% or more to the effective dose equivalent, but the calculated effective dose equivalent considers all organs.

(c) To be used when assumption (b) does not hold.