11.0 Cobalt-60 and Corrosion Products

This chapter provides background on the sources, characteristics, and biokinetic behavior of ^{60}Co and other corrosion product radionuclides and summarizes the technical basis used for their internal dosimetry at Hanford.

11.1 Sources and Characteristics of Corrosion Product Radionuclides

Corrosion product radionuclides are created by neutron activation of reactor components such as piping or fuel element cladding. The principal sources of corrosion product radionuclides at Hanford are the old reactor facilities, such as N Reactor (operated until 1986); however, FFTF can also be a source. In addition, corrosion products can be found in workers who have had intakes at other nuclear facilities, notably nuclear power plants or naval shipyards servicing nuclear-powered vessels. Corrosion product radionuclides are generally high-energy gamma-emitters; therefore, bioassay monitoring can be readily accomplished by whole body counting. Historically, fresh corrosion product radionuclides, regardless of origin, were usually a mixture of several radionuclides. The predominant radionuclide was usually ^{60}Co, with ^{58}Co, ^{54}Mn, and ^{59}Fe as the other significant constituents in a fresh mixture. Other radionuclides were often present in trace amounts, but they were generally of little dosimetric consequence. The relative abundance of the radionuclides varied from facility to facility. However, given the time elapsed since operation of the reactors at Hanford, the short-lived corrosion products have decayed away, leaving ^{60}Co as the nuclide of concern. Radiological decay data for the common corrosion products are shown in Table 11.1.

Table 11.1. Radiological Data for Common Corrosion Products

Isotope	Half-Life	Decay Constant	Specific Activity (Ci/g)
^{60}Co	5.27 y	1.31E-01 y^{-1}	1.13E+03
^{58}Co	70.8 d	9.79E-03 d^{-1}	3.17E+04
^{54}Mn	313 d	2.21E-03 d^{-1}	7.69E+03
^{59}Fe	44.5 d	1.56E-02 d^{-1}	4.95E+04

A detailed characterization of these corrosion products during N Reactor operations was performed by Weetman and DeHaven (1982a; 1982b). This work indicated that airborne particulates containing corrosion product radionuclides could be characterized by a lognormal distribution with an AMAD ranging from 0.5 μm to

2.5 μm. Unless specific information is available, the assumption of a 1-μm-AMAD particulate is recommended for evaluations of internal exposure. This recommendation runs counter to the 5-μm-AMAD particle size used elsewhere in this manual.

For mixtures containing corrosion product radionuclides, the pulmonary retention of the individual radionuclides is probably influenced by the contaminant carrier matrix; thus, pulmonary retention for all of the radionuclides within a single carrier matrix may be similar. Oxides characteristically represent the least transportable form of an element in the lung. For purposes of *a priori* calculations of expected dose from intake, the transportability class for the oxide form of the radionuclide is assumed. Nevertheless, retrospective assessment of internal dose following an intake should be based on actual observed retention in the lung.

11.2 Biokinetic Behavior of Corrosion Product Radionuclides

The biokinetic behavior of corrosion product radionuclides in the body is influenced by the physical and chemical properties of the host matrix, as well as the individual elements composing the matrix. Thus, the actual behavior of the material following intake is dependent on numerous complex and competing factors. Although there have been numerous historical cases involving inhalation intakes of corrosion products at Hanford, the intakes involved have been too small to enable the specific radionuclide versus host matrix characteristics to be accurately described. The approach taken here regarding assumptions for distribution and retention of corrosion product radionuclides is to assume that the radionuclide behaves according to the most insoluble form established for the element in ICRP 30 (1979) unless sufficient in vivo data are available and the intake is of sufficient magnitude (e.g., potentially above 100 mrem) to warrant evaluation of individual-specific retention.

11.2.1 Transportability Class

ICRP 30 establishes default inhalation classes W and Y for cobalt, and classes D and W for both manganese and iron. The CINDY computer code (Strenge et al. 1992) implements the biokinetic models described in ICRP 30 and is used to assess expected bioassay compartment quantities following intakes of the corrosion products. The biokinetic parameters of CINDY can also be modified to provide a better agreement between observed and expected bioassay compartment values.

The new ICRP 66 lung model (ICRP 1994a) introduced the concept of lung absorption type as a replacement for the ICRP 30 inhalation class. Table 11.2 shows both the ICRP 30 inhalation class and the absorption type tabulated in ICRP publications 68 and 78 (ICRP 1994b; 1997).

Table 11.2. Lung Absorption and GI Uptake Factors for Corrosion Product Elements

Isotope	Chemical Form	Inhalation Class[(a)]	Lung Absorption Type [(b)]	GI Uptake, f_1 [(b)]
Co	Oxides, hydroxides, halides, nitrates,	Y	S	0.05
	All other compounds	W	M	0.1
Mn	Oxides, hydroxides, halides, nitrates,	W	M	0.1
	All other compounds	D	F	0.1
Fe	Oxides, hydroxides, halides	W	M	0.1
	All other compounds	D	F	0.1

(a) Based on ICRP 30.
(b) Based on ICRP 68 and 78.

Because corrosion products are typically oxides, the oxide form of these elements is assumed for Hanford internal dosimetry unless other information is available. Consequently, the default inhalation classes for Hanford intakes of corrosion products are class Y for cobalt and W for manganese and iron.

11.2.2 Gastrointestinal Uptake to Blood (f_1 Factor)

The gastrointestinal uptake (f_1) factors for the corrosion products discussed in this section are shown in Table 11.2. No changes were made in the uptake factors between ICRP publication 30 and publications 67 (1993) and 78 for insoluble forms. The uptake factor for moderately insoluble forms of cobalt increased from 0.05 to 0.1. The extent of absorption of iron by the GI tract depends on a number of factors, including the amount of iron in the diet, its chemical form, the body's iron needs, and the presence of interfering substances in the diet.

11.2.3 Biokinetic Models

Cobalt

The ICRP 30 Part 1 (1979) model for cobalt is used by the HIDP. This model was also used in ICRP publication 78. Of the cobalt entering the blood stream, half (0.5) is excreted directly with a

half-time of 0.5 days, with the remaining half (0.5) distributed in the body. Of the amount distributed in the body, 10% is assumed to go to the liver and the remaining 90% is distributed throughout the rest of the body. The material deposited in body organs (other than lung) is removed from the organs at several rates. In the absence of retention data on a case-specific basis, the ICRP recommends that the following retention half-lives be applied to the material in the liver and rest of body:

Fraction Retained	Biological Half-Life, Days
0.6	6
0.2	60
0.2	800

Because the retention characteristics are considered to be the same for the liver as for the rest of the body, the relative distribution can be assumed to be constant at 10% in the liver and 90% in all other body tissues (except lung). Excretion from the systemic compartment is assumed to be fractionated to urine (0.7) and feces (0.3), as assumed by ICRP publication 54 (1988).

Manganese

The HIDP uses the ICRP 30 Part 1 (1979) model for manganese entering the blood stream. It assumes distribution among bone surfaces, liver compartments, and all other soft tissue compartments as follows:

Compartment	Fraction Retained	Biological Half-Life, Days
Bone Surfaces	0.35	40
Liver 1	0.10	4
Liver 2	0.15	40
Soft Tissue 1	0.2	4
Soft Tissue 2	0.2	40

ICRP publication 54 noted that there were no reliable data on systemic excretion of manganese, thus it is assumed that systemic excretion is evenly split between urine and feces.

Iron

The ICRP 30 Part 2 (1980) model for iron entering the blood stream, distributes it according to the following fractionation:

Tissue	Fraction	Biological Half-Life, Days
Liver	0.08	2,000
Spleen	0.013	2,000
Rest of Body	0.907	2,000

Regardless of the site of deposition, iron is assumed to have a biological half-life of 2000 days, so the above organ distribution can be assumed to remain fixed following intake. ICRP has not provided any recommended fractionation for the systemic excretion of iron, thus it is assumed that systemic excretion is evenly split between urine and feces.

11.3 Internal Dosimetry Factors for Corrosion Products

This section contains factors that are useful in making internal dosimetry calculations. The factors included in this section are derived from the CINDY computer code and incorporate the models and assumptions of the preceding sections. Their application is intended for circumstances where such assumptions are appropriate or more specific information is lacking. Variation from these factors is appropriate if sufficient data are available.

11.3.1 Whole Body Retention for Corrosion Products

The whole body retention fractions for ingestion and inhalation of oxides of ^{60}Co, ^{54}Mn, and ^{59}Fe are shown in Table 11.3, 11.4, and 11.5, respectively. The fractions are based on inhalation of 1-µm- and 5-µm-AMAD particle sizes for class Y ^{60}Co, class W ^{54}Mn, and class W ^{59}Fe. Two particle sizes are addressed because the 1-µm particle size is the Hanford default value (based on Hanford facility air sample data discussed previously), and the 5-µm particle size is now recommended by the ICRP. Excretion fractions have not been provided because whole body counting data are typically used for these nuclides and retention can be directly determined. Retention or excretion fractions for other forms of these radionuclides can be calculated using the CINDY code.

11.3.2 Dose Coefficients

Dose coefficients, expressed as committed dose equivalent per unit activity of intake (e.g., rem/nCi), are a convenient shortcut to estimating doses based on standard assumptions when the magnitude of an intake is known. Acute intake dose coefficients have been tabulated for selected exposure scenarios. The scenarios include the inhalation of 1-µm- and 5-µm-AMAD particles as the Hanford default and ICRP 66 default particle sizes, respectively, and ingestion. Chemical forms tabulated are the oxide forms, considered the most likely to be encountered. For all of these scenario conditions the most limiting dose coefficients are for the committed effective dose equivalent. Those dose coefficients are listed in Table 11.6.

Table 11.3. Whole Body Retention for ^{60}Co

Days Post Intake	Inhalation 1-mm-AMAD Class Y	Inhalation 5-mm-AMAD Class Y	Ingestion f_1=0.05
0	6.3E-01	9.1E-01	1.0E+00
1	5.8E-01	8.0E-01	7.1E-01
2	4.2E-01	5.0E-01	3.3E-01
5	1.9E-01	1.1E-01	3.6E-02
7	1.7E-01	7.6E-02	1.9E-02
14	1.5E-01	6.5E-02	1.3E-02
30	1.5E-01	6.0E-02	8.9E-03
60	1.4E-01	5.6E-02	7.1E-03
90	1.4E-01	5.3E-02	6.2E-03
180	1.2E-01	4.6E-02	4.6E-03
365	9.4E-02	3.6E-02	3.3E-03
730	5.9E-02	2.2E-02	2.0E-03
1825	1.6E-02	6.2E-03	5.3E-04
3600	3.0E-03	1.1E-03	6.1E-05
7300	3.1E-04	1.1E-04	6.5E-07
18250	5.3E-06	1.9E-06	1.2E-12

Table 11.4. Whole Body Retention for ^{54}Mn

Days Post Intake	Inhalation 1-mm-AMAD Class W	Inhalation 5-mm-AMAD Class W	Ingestion f_1=0.1
0	6.3E-01	9.1E-01	1.0E+00
1	5.9E-01	8.2E-01	7.3E-01
2	4.6E-01	5.7E-01	3.8E-01
5	2.6E-01	2.3E-01	9.4E-02
7	2.3E-01	1.9E-01	7.3E-02
14	1.9E-01	1.5E-01	5.7E-02
30	1.5E-01	1.1E-01	3.9E-02
60	9.8E-02	6.7E-02	2.2E-02
90	6.3E-02	4.1E-02	1.2E-02
180	1.7E-02	9.2E-03	2.1E-03
365	1.2E-03	5.0E-04	5.6E-05
730	5.1E-06	1.9E-06	4.5E-08

Table 11.5. Whole Body Retention for ^{59}Fe

Days Post Intake	Inhalation 1-mm-AMAD Class W	Inhalation 5-mm-AMAD Class W	Ingestion f_1=0.1
0	6.3E-01	9.1E-01	1.0E+00
1	5.8E-01	8.2E-01	7.2E-01
2	4.6E-01	5.7E-01	3.7E-01
5	2.6E-01	2.5E-01	1.1E-01
7	2.3E-01	2.2E-01	9.2E-02
14	2.0E-01	1.9E-01	8.0E-02
30	1.5E-01	1.4E-01	6.2E-02
60	8.3E-02	8.7E-02	3.9E-02
90	4.8E-02	5.3E-02	2.4E-02
180	1.1E-02	1.2E-02	5.8E-03
365	5.4E-04	6.6E-04	3.1E-04
730	1.7E-06	2.1E-06	9.8E-07

Table 11.6. Dose Coefficients ($h_{e,50}$) for Corrosion Products (rem/nCi)

Radionuclide	Inhalation 1-mm-AMAD	Inhalation 5-mm-AMAD	Ingestion
^{60}Co	2.0E-04 (Class Y)	7.9E-05 (Class Y)	1.0E-05 (f_1=0.05)
^{54}Mn	6.0E-06 (Class W)	4.2E-06 (Class W)	2.1E-06 (f_1=0.1)
^{59}Fe	1.2E-05 (Class W)	1.0E-05 (Class W)	5.9E-06 (f_1=0.1)

Organs of significance (i.e., those contributing greater than 10% of the committed effective dose equivalent) can be determined from the CINDY code based on actual intake assessment data.

11.3.3 Comparison of Published Dosimetry Factors

A comparison of selected dosimetry factors for ^{60}Co is shown in Table 11.7. Similar comparisons with ^{54}Mn and ^{59}Fe have been omitted because of the lack of a Hanford source for these materials at this time. Their potential interest is mainly of a historical nature.

11.3.4 Derived Reference Levels

Derived reporting, investigation, and dose limit compliance levels (based on committed effective dose equivalents of 10-mrem, 100-mrem, and 5,000 mrem, respectively) have been calculated for

Table 11.7. Comparison of Dosimetric Factors for ^{60}Co

Reference Source	Class Y Inhalation 1-mm-AMAD	Class Y Inhalation 5-mm-AMAD	Soluble Ingestion (f_1 = 0.05)
Dose Coefficients			
CINDY [$h_{E,50}$]	2.0E-04 mrem/nCi 5.4E-08 Sv/Bq	7.9E-05 rem/nCi 2.1E-08 Sv/Bq	1.0E-05 rem/nCi 2.7E-09 Sv/Bq
ICRP 54 [$h_{E,50}$]	4.1E-08 Sv/Bq (1.5E-04 rem/nCi)	NA	NA
EPA Federal Guidance Report No.11 [$h_{E,50}$]	5.91E-08 Sv/Bq (2.19E-04 rem/nCi)	NA	7.28E-09 Sv/Bq (2.69E-05 rem/nCi)
ICRP 68 [e(50)]	2.9E-08 Sv/Bq (1.1E-04 rem/nCi) Type S	1.7E-08 Sv/Bq (6.3E-05 rem/nCi) Type S	2.5E-09 Sv/Bq (9.3E-06 rem/nCi)
Stochastic DAC			
10 CFR 835, App. A	1E-08 µCi/ml and 5E+02 Bq/m^3	NA	NA
EPA Federal Guidance Report No. 11	1E-08 µCi/ml and 5E-04 MBq/m^3	NA	NA
ICRP 30, ICRP 54	5E+02 Bq/ m^3	NA	NA
Stochastic Annual Limit on Intake, ALI			
Calculated from 10 CFR 835 DAC	19 µCi and 7.2E+05 Bq	NA	NA
ICRP 30	1E+06 Bq	NA	1E+06 Bq
ICRP 54	1E+06 Bq	NA	NA
EPA Federal Guidance Report No. 11	1 MBq and 30 µCi	NA	7 MBq and 200 µCi
NA = not applicable			

^{60}Co oxides. These levels are shown in Table 11.8 for 1-µm-AMAD class Y inhalation, Table 11.9 for 5-µm-AMAD class Y inhalation, and Table 11.10 for ingestion.

11.4 Bioassay for Corrosion Products

This section discusses the bioassay methods, capabilities, and protocols for corrosion products.

11.4.1 Bioassay Methods and Capabilities

In vivo and excreta measurements are the bioassay methods used in monitoring for corrosion product radionuclides. All of the radionuclides included in this section are gamma-emitters and can be measured directly using in vivo techniques. Whole body counting, using either sodium-iodide or coaxial germanium detectors, is the in vivo technique typically applied for bioassay of these nuclides.

Table 11.8. ^{60}Co Whole Body Reference Levels for 1-µm-AMAD Class Y Inhalation

	10-mrem $H_{E,50}$ Reporting Level	100-mrem $H_{E,50}$ Investigation Level	5-rem $H_{E,50}$ Compliance Level
Inhalation Intake (nCi)	5.0E+01	5.0E+02	2.5E+04
Days Post Intake	**Derived Reporting Level (nCi)**	**Derived Investigation Level (nCi)**	**Derived Compliance Level (nCi)**
0	3.2E+01	3.2E+02	1.6E+04
1	2.9E+01	2.9E+02	1.5E+04
2	2.1E+01	2.1E+02	1.1E+04
5	9.5E+00	9.5E+01	4.8E+03
7	8.5E+00	8.5E+01	4.3E+03
14	7.5E+00	7.5E+01	3.8E+03
30	7.5E+00	7.5E+01	3.8E+03
60	7.0E+00	7.0E+01	3.5E+03
90	7.0E+00	7.0E+01	3.5E+03
180	6.0E+00	6.0E+01	3.0E+03
365	4.7E+00	4.7E+01	2.4E+03
730	3.0E+00	3.0E+01	1.5E+03
1825	8.0E-01	8.0E+00	4.0E+02
3650	1.5E-01	1.5E+00	7.5E+01
7300	1.6E-02	1.6E-01	7.8E+00
18250	2.7E-04	2.7E-03	1.3E-01

Table 11.9. ^{60}Co Whole Body Reference Levels for 5-µm-AMAD Class Y Inhalation

	10-mrem $H_{E,50}$ Reporting Level	100-mrem $H_{E,50}$ Investigation Level	5-rem $H_{E,50}$ Compliance Level
Inhalation Intake (nCi)	1.3E+02	1.3E+03	6.3E+04
Days Post Intake	**Derived Reporting Level (nCi)**	**Derived Investigation Level (nCi)**	**Derived Compliance Level (nCi)**
0	1.2E+02	1.2E+03	5.8E+04
1	1.0E+02	1.0E+03	5.1E+04
2	6.3E+01	6.3E+02	3.2E+04
5	1.4E+01	1.4E+02	7.0E+03
7	9.6E+00	9.6E+01	4.8E+03
14	8.2E+00	8.2E+01	4.1E+03
30	7.6E+00	7.6E+01	3.8E+03
60	7.1E+00	7.1E+01	3.5E+03
90	6.7E+00	6.7E+01	3.4E+03
180	5.8E+00	5.8E+01	2.9E+03
365	4.6E+00	4.6E+01	2.3E+03
730	2.8E+00	2.8E+01	1.4E+03
1825	7.8E-01	7.8E+00	3.9E+02
3650	1.4E-01	1.4E+00	7.0E+01
7300	1.4E-02	1.4E-01	7.0E+00
18250	2.4E-04	2.4E-03	1.2E-01

Table 11.10. ^{60}Co Whole Body Reference Levels for Ingestion (f_1 = 0.05)

		10-mrem $H_{E,50}$ Reporting Level	100-mrem $H_{E,50}$ Investigation Level	5-rem $H_{E,50}$ Compliance Level
Inhalation Intake (nCi)		1.0E+03	1.0E+04	5.0E+05
Days Post Intake	**Whole Body IRF**	**Derived Reporting Level (nCi)**	**Derived Investigation Level (nCi)**	**Derived Compliance Level (nCi)**
0	1.0E+00	1.0E+03	1.0E+04	5.0E+05
1	7.1E-01	7.1E+02	7.1E+03	3.6E+05
2	3.3E-01	3.3E+02	3.3E+03	1.7E+05
5	3.6E-02	3.6E+01	3.6E+02	1.8E+04
7	1.9E-02	1.9E+01	1.9E+02	9.5E+03
14	1.3E-02	1.3E+01	1.3E+02	6.5E+03
30	8.9E-03	8.9E+00	8.9E+01	4.5E+03
60	7.1E-03	7.1E+00	7.1E+01	3.6E+03
90	6.2E-03	6.2E+00	6.2E+01	3.1E+03
180	4.6E-03	4.6E+00	4.6E+01	2.3E+03
365	3.3E-03	3.3E+00	3.3E+01	1.7E+03
730	2.0E-03	2.0E+00	2.0E+01	1.0E+03
1825	5.3E-04	5.3E-01	5.3E+00	2.7E+02
3650	6.1E-05	6.1E-02	6.1E-01	3.1E+01
7300	6.5E-07	6.5E-04	6.5E-03	3.3E-01
18250	1.2E-12	1.2E-09	1.2E-08	6.0E-07

Because the radionuclides are easily detectable using in vivo measurement, excreta measurements are not required in most intake situations, unless there is concern for other radionuclides such as strontium or plutonium, which are not readily measurable by in vivo techniques. Measurement of radionuclides in early fecal excretion can be used as a means for establishing the relative radionuclide distribution in a corrosion product mixture; however, analysis of a nasal or appropriate surface contamination smear sample is preferred if the elements present may exhibit different absorption characteristics in the GI tract.

Tables 11.11, 11.12, and 11.13 describe the nominal Hanford minimum detectable intakes and minimum detectable committed effective dose equivalents for class Y inhalations and ingestion of ^{60}Co. The MDAs associated with the Hanford bioassay measurements are below those routinely used at many nuclear power plant facilities. Thus, it is possible that corrosion product activity detected by baseline Hanford measurements can be related to previously undetected intakes performed at facilities with less-sensitive MDAs.

Table 11.11. ^{60}Co Minimum Detectable Intakes and Doses ($H_{E,50}$) for 1-µm-AMAD Class Y Inhalation

Days Post Intake	NaI System[(a)] Minimum Detectable		Coax Ge System[(b)] Minimum Detectable	
	Intake (nCi)	Dose (mrem)[(c)]	Intake (nCi)	Dose (mrem)[(c)]
0	2.1	0.4	1.0	0.2
1	2.2	0.4	1.0	0.2
2	3.1	0.6	1.4	0.3
5	6.8	1.4	3.2	0.6
7	7.6	1.5	3.5	0.7
14	8.7	1.7	4.0	0.8
30	8.7	1.7	4.0	0.8
60	9.3	1.9	4.3	0.9
90	9.3	1.9	4.3	0.9
180	11	2.2	5.0	1.0
365	14	2.8	6.4	1.3
730	22	4.4	10	2.0
1825	81	16	37	7.5
3600	430	87	200	40
7300	4200	840	1900	390

(a) Based on MDA of 1.3 nCi
(b) Based on MDA of 0.6 nCi
(c) Dose values less than 1 mrem are rounded to the nearest tenth.

Table 11.12. ^{60}Co Minimum Detectable Intakes and Doses ($H_{E,50}$) for 5-µm-AMAD Class Y Inhalation

Days Post Intake	NaI System[(a)] Minimum Detectable		Coax Ge System[(b)] Minimum Detectable	
	Intake (nCi)	Dose (mrem)[(c)]	Intake (nCi)	Dose (mrem)[(c)]
0	1.4	0.1	0.7	0.1
1	1.6	0.1	0.8	0.1
2	2.6	0.2	1.2	0.1
5	12	0.9	5.5	0.4
7	17	1.4	7.9	0.6
14	20	1.6	9.2	0.7
30	22	1.7	10	0.8
60	23	1.8	11	0.8
90	25	1.9	11	0.9
180	28	2.2	13	1.0
365	36	2.9	17	1.3
730	59	4.7	27	2.2
1825	210	17	97	7.6
3600	1200	93	550	43
7300	12,000	930	5500	430

(a) Based on MDA of 1.3 nCi
(b) Based on MDA of 0.6 nCi
(c) Dose values less than 1 mrem are rounded to the nearest tenth.

Table 11.13. ^{60}Co Minimum Detectable Intakes and Doses ($H_{E,50}$) for Ingestion[a]

Days Post Intake	NaI System[b] Minimum Detectable		Coax Ge System[c] Minimum Detectable	
	Intake (nCi)	Dose (mrem)[d]	Intake (nCi)	Dose (mrem)[d]
0	1.3	0.0	0.6	0.0
1	1.8	0.0	0.8	0.0
2	3.9	0.0	1.8	0.0
5	36	0.4	17	0.2
7	68	0.7	32	0.3
14	100	1.0	46	0.5
30	150	1.5	67	0.7
60	180	1.8	85	0.8
90	210	2.1	97	1.0
180	280	2.8	130	1.3
365	390	3.9	180	1.8
730	650	6.5	300	3.0
1825	2500	25	1100	11
3600	21,000	210	9800	98

(a) Based on f_1 = 0.05.
(b) Based on MDA of 1.3 nCi.
(c) Based on MDA of 0.6 nCi.
(d) Dose values less than 1 mrem are rounded to nearest tenth.

11.4.2 Routine Bioassay Monitoring Protocol

Routine monitoring for gamma-emitting corrosion products is best accomplished by periodic whole body counting. With ^{60}Co as the predominant corrosion product, Tables 11.8 through 11.10 show that minimum detectable doses of 10 mrem can be achieved with annual whole body counts having an MDA of 3 nCi. Such an MDA is readily achievable with the Hanford preview counter—a standup NaI detector system. Definitive measurements using the coaxial germanium detector system are preferred for identification and quantification of gamma-emitting nuclides due to the much higher resolution of that system and a lower MDA. Consequently, initial detection of a gamma-emitter such as ^{60}Co on the NaI system should be followed by a verification count on the coaxial germanium system, preferably immediately following the initial measurement, while the subject is still at the IVRRF.

If, at very low indicated activities, a follow-up measurement is not obtained or a contractor wishes to waive the follow-up measurement, dose equivalents can be calculated based on the single initial count. Although the accuracy of a single count performed using the preview counter is somewhat less than that obtained using germanium detector systems, this higher uncertainty is not of much significance at low doses.

11.4.3 Special Monitoring for Suspected Intakes

An in vivo examination should be performed following any indication of an intake of activated corrosion product radionuclides. However, unless the intake appears to be of such a magnitude that medical treatment to aid removal of the material from the body is considered, the exam may be scheduled as convenient, within several days of the intake without significant loss of sensitivity to intake detection. All radionuclides potentially involved in the exposure should be considered during the follow-up investigation.

The interpretation of in vivo measurements shortly after intake may be complicated by early transport of material through the lung and GI tract. Measurements performed after about 5 days post intake are more appropriate for dose evaluation. Long-term follow-up bioassay measurements should be considered to monitor internal radioactivity levels and establish individual-specific retention characteristics.

11.5 Assessment of Internal Dose

The assessment of internal dose equivalent from corrosion products is accomplished by evaluating in vivo measurement results. Assessments of internal dose equivalents for intakes of mixtures of corrosion product radionuclides must consider the contribution of all radionuclides present in the mixture. The variability of the corrosion product mixtures and their change in composition with time due to radioactive decay precludes the establishment of a generic mixture.

The committed effective dose equivalent is calculated for any intake confirmed by special bioassay measurements, and for periodic measurements that exceed the screening levels contained in the *Hanford Internal Dosimetry Program Manual*.[(a)] Committed dose equivalents to specific organs and tissues are determined based on the criteria also presented in the *Hanford Internal Dosimetry Program Manual*. Several methods exist to evaluate in vivo results in order to assess the internal dose equivalent. The simplest method, and the one recommended for initial evaluation of in vivo results, as well as for final evaluations when doses are low, involves fitting the in vivo measurement data to the expected internal activity using the biokinetic model prescribed by the ICRP in publication 30. This model is implemented using CINDY. Assumptions that are used for this evaluation are 1) that the material is in its most insoluble form; 2) that the intake date, if unknown, is assumed to be the midpoint of

(a) Pacific Northwest National Laboratory. 1999. *Hanford Internal Dosimetry Program Manual*. PNL-MA-552, Richland, Washington. (Internal manual.) Available URL: http://www.pnl.gov/eshs/pub/pnnl552.htm

the period during which the intake could have occurred; and 3) that the intake consisted of inhalation of an aerosol with 1-µm-AMAD particles. Data fitting is performed using CINDY. Alternatively, a hand calculation can be performed using the factors tabulated in this chapter.

If the intake could potentially result in a committed effective dose equivalent exceeding 100 mrem, then an investigation should be performed to determine the radionuclide composition of the involved corrosion product mixture and to assess the dose equivalent from all radionuclides present in the mixture. Additional in vivo measurements to confirm the assumed retention function, or to develop a case-specific retention function, should also be performed.

Observed in vivo retention of corrosion product radionuclides should be used in place of the ICRP biokinetic model for evaluations of internal doses that potentially exceed 100 mrem or when sufficient in vivo data are available for such an analysis. This can be accomplished by modifying distribution and retention parameters in CINDY to achieve better agreement between the model and the observed in vivo measurement data. Modifications to default model parameters must be documented in the internal dose assessment report.

11.6 Management of Internal Contamination Cases

Historically, during reactor operations, activated corrosion product radionuclides were the most common type of internal exposure at Hanford. However, exposures were minor and there is no known instance in which special therapeutic measures were applied for mitigative purposes. Various options exist for treatment to remove corrosion product radionuclides from the body. These generally involve measures to minimize absorption into the blood, including stomach lavage and administration of purgatives, emetics, or phytates. Use of chelating agents may also be considered in significant exposure cases. A primary consideration for all mitigatory actions is prompt response because the effectiveness of treatment decreases rapidly with time post intake. Occupational Medicine at HEHF should be notified immediately upon indication of a severe intake of corrosion product radionuclides.

11.7 References

10 CFR 835. 1998. U.S. Department of Energy. "*Occupational Radiation Protection*." U.S. Code of Federal Regulations.

International Commission on Radiological Protection (ICRP). 1979. "Limits for intakes of radionuclides by workers." (ICRP publication 30, part 1). *Annals of the ICRP*, 2:3-4, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1980. "Limits for intakes of radionuclides by workers." (ICRP publication 30, part 2). *Annals of the ICRP*, 4:3-4, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1988. "Individual monitoring for intakes of radionuclides by workers: Design and interpretation." (ICRP publication 54). *Annals of the ICRP,* 19:1-3, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1993. "Age-dependent doses to members of the public from intake of radionuclides: Part 2 ingestion dose coefficients." (ICRP publication 67). *Annals of the ICRP*, 23:3-4, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1994a. "Human respiratory tract model for radiological protection." (ICRP publication 66). *Annals of the ICRP,* 24:1-3, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1994b. "Dose coefficients for intakes of radionuclides by workers." (ICRP publication 68). *Annals of the ICRP*, 24:4, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1997. "Individual monitoring for internal exposure of workers." (ICRP publication 78). *Annals of the ICRP*, 27:3-4, Pergamon Press, New York.

Strenge, D. L., R. A. Kennedy, M. J. Sula, and J. R. Johnson. 1992. *Code for Internal Dosimetry (Cindy Version 1.2), Part 1: Conceptual Representation*. PNL-7493 Pt. 1, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Environmental Protection Agency (EPA). 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.* Federal Guidance Report No. 11, EPA-520/1-88-020, Washington, D.C.

Weetman, R. A., and H. W. DeHaven. 1982a. *Characterization of Airborne Radionuclides in UNC Facilities*. UNI-2164, UNC Nuclear Industries, Richland, Washington.

Weetman, R. A., and H. W. DeHaven. 1982b. *Characterization of Surface Contamination in UNC Facilities*. UNI-2137, UNC Nuclear Industries, Richland, Washington.