

**SECTION 3.0**

**COBALT-60 AND OTHER  
CORROSION PRODUCT RADIONUCLIDES**

### 3.0 COBALT-60 AND OTHER 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 N Reactor and FFTF. Corrosion product radionuclides are generally gamma-emitters; therefore, bioassay monitoring can be readily accomplished by whole body counting. This section provides background on the sources, characteristics, and biokinetic behavior of  $^{60}\text{Co}$  and other corrosion product radionuclides and summarizes the technical basis used for their internal dosimetry at Hanford.

#### 3.1 SOURCES AND CHARACTERISTICS OF CORROSION PRODUCT RADIONUCLIDES

In recent years, the primary source of corrosion product radionuclides at Hanford has been the N Reactor, and the most detailed characterization of these radionuclides has been performed for N Reactor facilities (Weetman and DeHaven 1982a, 1982b). In general, a major characteristic of these corrosion product radionuclides, regardless of origin, is the presence of several radionuclides within a matrix of oxidized metal with  $^{60}\text{Co}$  the predominant radionuclide.

The constituents of most corrosion product mixtures of an internal dosimetry concern at Hanford have historically been  $^{58}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{54}\text{Mn}$ , and  $^{59}\text{Fe}$ . Other radionuclides may also be present in trace amounts, but they are generally of little dosimetric significance. These radionuclides are all associated with elements found in steel and alloys used in reactor components. The relative abundance of the radionuclides varies from facility to facility; however,  $^{60}\text{Co}$  is generally the predominant radionuclide in terms of both activity and dose significance. With the shutdown of N Reactor in 1987, the production of corrosion product radionuclides at Hanford is currently limited to FFTF. Based on historical experience,  $^{60}\text{Co}$  is the best indicator of an intake of mixtures of corrosion product radionuclides.

Studies at N Reactor indicate that airborne particulates containing corrosion product radionuclides can be characterized by a lognormal distribution with an activity median aerodynamic diameter (AMAD) ranging from 0.5 to 2.5  $\mu\text{m}$

(Weetman and DeHaven 1982a). Unless specific information is available, the assumption of a 1- $\mu$ m-AMAD particulate is recommended for evaluations of internal exposure.

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 will probably 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.

### 3.2 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 several 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/yr) to warrant evaluation of individual specific retention.

ICRP 30 establishes default inhalation classes W and Y for cobalt, and classes D and W for both manganese and iron. Therefore, for intakes involving a mixture of corrosion products, assumed inhalation classes are Y for cobalt and W for manganese and iron. Other radionuclides identified in the host matrix should be evaluated in the same manner. The GENMOD computer code (Johnson and Carver 1981) implements the biokinetic model prescribed in ICRP

30 and is used to assess expected bioassay compartment quantities following intakes of the corrosion products. As described in Appendix A, GENMOD also permits modification of biokinetic parameters to provide a better agreement between observed and expected bioassay compartment values.

Section 3.7 summarizes default biokinetic parameters to be used for assessing internal dose equivalents from intakes of corrosion product radionuclides

### 3.3 INTERNAL DOSIMETRY FOR CORROSION PRODUCTS

Section 3.7 provides radiological and dosimetric data for several corrosion product radionuclides. Tables 3.5, 3.11, and 3.15 provide estimates of the first-year and 50-year committed effective dose equivalents for intakes of the radionuclides and Tables 3.6, 3.7, 3.12, and 3.16 give expected activities remaining in the lung and whole body following an intake sufficient to result in a first-year effective dose equivalent of 10 mrem.

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 relative contribution to internal dose equivalent by the various radionuclides precludes the establishment of any specific relationship between effective dose equivalent and organ doses for a generic mixture.

In vivo measurements permit the actual distribution and retention of the radionuclides in the body to be estimated. In vivo measurements are capable of providing estimates of activity in the lung and in the total body following an intake. Subtraction of lung activity from total body activity yields an estimate of the activity in systemic compartments of the body for measurements performed more than 1 week post intake (after clearance of any ingested or inhaled material from the gastrointestinal [GI] tract). Activity in the systemic compartments is distributed among several organs and assessment of the activity in these compartments is normally not feasible using standard in vivo measurement techniques. In lieu of specific information regarding the inter-systemic partitioning of the radionuclides, the organ deposition fractions and retention rates provided in ICRP 30 are used. Thus, successive

whole body counts yield data from which lung and systemic organ cumulative activities (e.g., nCi-days) can be determined. The dose conversion factors listed in Section 3.7 in Tables 3.4, 3.10, and 3.14 may be applied to these cumulative activities over the time periods of interest to assess organ and effective dose equivalents.

### 3.4 BIOASSAY FOR CORROSION PRODUCTS

The following subsections discuss bioassay monitoring for corrosion product radionuclides.

#### 3.4.1 Bioassay Methods

In vivo and excreta measurements comprise the bioassay methods used in monitoring for corrosion product radionuclides.

##### In Vivo Measurements

All of the radionuclides included in this section are gamma-emitters; therefore, internally deposited activities can be measured directly using in vivo techniques. Table 3.1 shows the detection levels for the radionuclides using the standard three-minute preview counter measurement (Palmer et al. 1990).

TABLE 3.1. Minimum Detectable Activity in a Whole Body Count (preview counter, 3-minute count)<sup>(a)</sup>

<u>Radionuclide</u>	<u>MDA, nCi</u>
<sup>58</sup> Co	3
<sup>60</sup> Co	3
<sup>54</sup> Mn	3
<sup>59</sup> Fe	6

(a) MDA calculated as described by Palmer et al. (1990) and in Appendix C.

### Excreta Measurements

Because the radionuclides are easily detectable using in vivo techniques, it is not expected that excreta measurements would be required in most internal exposure situations. Measurement of radionuclides in early fecal excretion can be used as a means for establishing the relative radio-nuclide 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.

#### 3.4.2 Routine Bioassay Monitoring Program

Routine monitoring for gamma-emitting corrosion products is best accomplished by periodic whole body counting. Based on the tables in Section 3.7, which show the capability of periodic bioassay measurements in terms of annual and committed effective dose equivalent, a semiannual frequency provides for detection of intakes in a year resulting in either an annual or committed effective dose equivalent of 100 mrem for the radionuclides specifically covered in this section. An annual frequency would enable detection of annual effective doses of 100 mrem for all radionuclides considered except  $^{59}\text{Fe}$ .

Because corrosion product mixtures are characterized by the dominant presence of  $^{60}\text{Co}$ , a bioassay monitoring program for identifying intakes can be based on the identification of  $^{60}\text{Co}$ . For this approach to be valid, the presence of other radionuclides should be considered whenever  $^{60}\text{Co}$  is detected.

Because intakes of activated corrosion products usually involve several radionuclides, it is prudent to assume, upon initial assessment of bioassay measurement results, that the dose incurred from all radionuclides in the corrosion product mixture will exceed somewhat the dose received from  $^{60}\text{Co}$  alone. For example, if  $^{60}\text{Co}$ ,  $^{58}\text{Co}$ ,  $^{54}\text{Mn}$ , and  $^{59}\text{Fe}$  were present at equal activities in a mixture, then the first-year effective dose equivalent from an intake of the mixture would be about 1.4 times the dose equivalent received from the  $^{60}\text{Co}$ . However, because  $^{60}\text{Co}$  generally accounts for most of the activity in the mixture, doses from all radionuclides in the mixture are, in actual experience, less than 1.4 times the dose from the  $^{60}\text{Co}$  alone.

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<sup>59</sup> Fe	6

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### 3.5 ASSESSMENT OF INTERNAL DOSE EQUIVALENT

The assessment of internal dose equivalent from corrosion products is accomplished by evaluation of in vivo measurement results. Dose equivalents are assessed for any confirmed internal exposure attributed to occupational sources.

Dose assessments include annual and committed dose equivalents, as well as dose equivalents to specific organs of concern based on the criteria presented in the Hanford Internal Dosimetry Program Manual.<sup>(a)</sup> (See also Appendix B). Organs receiving the most dose following intake are those listed in Section 3.7, Tables 3.4, 3.10, and 3.14.

Several methods exist to evaluate in vivo results in order to assess the 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 doses are very 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 GENMOD. Assumptions that are used for this evaluation are that the material is in its most insoluble form, as recommended in ICRP 30; 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 intake consisted of inhalation of an aerosol with 1- $\mu$ m-AMAD particles. The resulting retention function, calculated using GENMOD, is fit to the observed in vivo measurement data using techniques described in Appendix C. Table 3.3 provides a summary of total body retention, expressed as a fraction of a unit acute intake, for selected times post intake. The tables in Section 3.7 that show in vivo retention at various times post intake can be used to estimate internal dose from whole body counting data.

If the intake could potentially result in an annual 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

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

mixture. Additional in vivo measurements to confirm the assumed retention function, or to develop a case-specific retention function, should also be performed.

For the purpose of developing an initial estimate of dose equivalent to determine the extent to which follow-up investigation is warranted, it should be assumed that the total dose received from intake of the corrosion product mixture is 1.4<sup>(a)</sup> times the dose contributed by <sup>60</sup>Co. This assumption accounts for the fact that <sup>60</sup>Co is usually part of a mixture of corrosion product radionuclides and not all radionuclides in the mixture may have been detected by the in vivo measurement.

A simplified dose assessment procedure for use in the initial evaluation, and as a final evaluation procedure for cases in which the annual effective dose equivalent is below 100 mrem, is as follows:

1. Determine time of intake. Assume the midpoint of the period during which the exposure could have occurred, if a specific intake date is not known. For example, for the evaluation of measured activity in an annual whole body count it might be assumed that the intake occurred at the midpoint of the measurement period, provided the worker could have incurred an intake at any time during the prior year.
2. As an initial evaluation of dose, evaluate the bioassay measurement results for each radionuclide detected using the ICRP 30 biokinetic model and assuming a) the least soluble form of the radionuclide recommended in ICRP 30, b) an acute inhalation intake, and c) an aerosol AMAD of 1  $\mu$ m. Table 3.3 provides selected total body retention fractions for various times post intake.
3. If <sup>54</sup>Mn and other corrosion product radionuclides were detected by the initial measurement(s), then assess the total annual dose received from these radionuclides. If the calculated dose exceeds a 100-mrem first-year effective dose equivalent, then determine if other radionuclides, not detected by the in vivo measurement, were also present at intake. Also, consider making additional in vivo measurements to confirm the retention characteristics of the material and re-establish baseline internal activity levels.

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(a) Assumes equal intake of <sup>60</sup>Co and <sup>54</sup>Mn. While other radionuclides may be involved, experience at Hanford indicates that the first-year dose is contributed mostly by these two radionuclides, and that the activity ratio of <sup>60</sup>Co to <sup>54</sup>Mn is always greater than 1.0.

4. If  $^{60}\text{Co}$  was the only radionuclide detected and its annual effective dose equivalent multiplied by 1.4 (to account for the possible contribution of other radionuclides present in a mixture) exceeds 100 mrem, then other radionuclides potentially present at intake, but not identified by the in vivo measurement, should be considered in the evaluation.

Observed in vivo retention of the corrosion product radionuclides should be used in place of the ICRP biokinetic model for evaluations of internal doses that potentially exceed 100 mrem/yr when sufficient in vivo data are available for such an analysis. This can be accomplished by either modifying retention/distribution parameters in GENMOD to achieve better agreement between the model and the observed in vivo measurement data, or by graphically analyzing the in vivo data to identify retention components for the lung and for systemic organs.<sup>(a)</sup> The retention curves are then integrated to obtain cumulative activity for the calendar years following intake, and the cumulative activity is multiplied by the organ and effective dose equivalent conversion factors in Tables 3.4, 3.10, or 3.14 to obtain annual dose equivalents. In order to provide a true assessment of the effective dose equivalent, the activity deposited in the lung, systemic organs, and tissues must be considered. Modifications to default model parameters must be documented in the internal/dose assessment report.

### 3.6 MANAGEMENT OF INTERNAL CONTAMINATION CASES

Historically, activated corrosion product radionuclides have been the most common type of internal exposure at Hanford. However, exposures have been minor and there is no known instance in which special therapeutic measures have been applied for mitigative purposes. Various options exist for treatment to remove corrosion product radionuclides from the body and 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

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(a) Activity in the systemic compartments of the body can be assumed to be represented by the activity in the total body minus the lung.

the effectiveness of treatment decreases rapidly with time post intake. Hanford Environmental Health Foundation Occupational Medicine, should be notified immediately upon indication of a severe intake of corrosion product radionuclides.

### 3.7 DOSIMETRY DATA FOR CORROSION PRODUCT RADIONUCLIDES

This section provides bioassay and dose assessment information for the principal corrosion product radionuclides:  $^{58}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{54}\text{Mn}$ , and  $^{59}\text{Fe}$ . Other radionuclides may sometimes be associated with intakes of mixed corrosion products; however, experience to date at Hanford has shown that they are of negligible dosimetric significance. If radionuclides other than those provided in this section are encountered, dose assessment can be accomplished using the methods discussed in this section.

#### 3.7.1 Cobalt-58 and Cobalt-60

Cobalt-60 is the primary corrosion product radionuclide. In essentially all internal exposure cases involving corrosion products at Hanford, the internally deposited activity and the resulting internal dose are both dominated by  $^{60}\text{Co}$ . Table 3.2 provides radiological data for  $^{58}\text{Co}$  and  $^{60}\text{Co}$ . According to ICRP 30, inhalation classes are assigned as follows:

TABLE 3.2. Radiological Data for  $^{58}\text{Co}$  and  $^{60}\text{Co}$

	<u><math>^{58}\text{Co}</math></u>	<u><math>^{60}\text{Co}</math></u>
Half-life	70.8 days	5.27 yr
Annual limit on intake <sup>(a)</sup>		
Class W	1100 $\mu\text{Ci}$	160 $\mu\text{Ci}$
Class Y	800 $\mu\text{Ci}$	27 $\mu\text{Ci}$
Whole body count MDA <sup>(b)</sup>	3 nCi	3 nCi

(a) From ICRP 30 (1979).

(b) MDA = minimum detectable activity (from Palmer et al. 1990).

- class Y--oxides, halides, nitrates, hydroxides
- class W--all other compounds.

As corrosion products, cobalt particulates exist in the oxide form and are considered to exhibit retention characteristics of class Y compounds. ICRP 30 considers cobalt to be relatively poorly absorbed by the GI tract and therefore assigns an absorption coefficient ( $f_1$ ) of 0.05 to both class W and Y compounds.

Of the cobalt entering the blood stream, about half is excreted directly, with the remaining half 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. According to ICRP 30, 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 rates be applied to the material in the liver and rest of body:

<u>Fraction Retained, %</u>	<u>Biological Half-Life, days</u>
60	6
20	60
20	800

Because the retention characteristics are considered to be the same for the liver as for the rest of the body, the relative distribution between the two sources can be assumed to be constant at the following percentages of total in the body (except lung):

- liver--10%
- rest of body--90%.

Table 3.3 shows  $^{58}\text{Co}$  and  $^{60}\text{Co}$  total body retention following an acute exposure to the most limiting ICRP inhalation class (class Y). Table 3.4 provides dose conversion factors (DCFs) (in rem/nCi-day) for  $^{58}\text{Co}$  and  $^{60}\text{Co}$  deposited in the lung and in systemic organs and tissues. Table 3.5 gives predicted first-year and 50-year committed effective dose equivalents per

TABLE 3.3. Total Body Retention<sup>(a)</sup> Following an Acute Inhalation Exposure to 1- $\mu$ m-AMAD Particles

<u>Days Post Intake</u>	<sup>58</sup> Co <u>Class Y</u>	<sup>60</sup> Co <u>Class Y</u>	<sup>54</sup> Mn <u>Class W</u>	<sup>59</sup> Fe <u>Class W</u>
0	6.30E-1	6.30E-1	6.30E-1	6.30E-1
1	5.71E-1	5.76E-1	5.88E-1	5.83E-1
2	4.14E-1	4.22E-1	4.63E-1	4.59E-1
5	1.82E-1	1.91E-1	2.58E-1	2.63E-1
7	1.55E-1	1.66E-1	2.27E-1	2.34E-1
14	1.36E-1	1.55E-1	1.93E-1	1.98E-1
30	1.13E-1	1.49E-1	1.51E-1	1.45E-1
60	8.10E-2	1.42E-1	9.77E-2	8.20E-2
90	5.85E-2	1.36E-1	6.34E-2	4.76E-2
180	2.21E-2	1.20E-1	1.73E-2	1.03E-2
365	3.03E-3	9.37E-2	1.17E-3	5.21E-4
730	6.20E-5	5.85E-2	5.43E-6	1.35E-6
1,825	0.00E+0	1.62E-2	2.83E-0	2.14E-0
3,650	0.00E+0	2.86E-3	0.00E+0	0.00E+0
7,300	0.00E+0	3.11E-4	0.00E+0	0.00E+0
18,250	0.00E+0	4.86E-6	0.00E+0	0.00E+0

(a) Expressed as fraction of a unit intake.

nanocurie of intake, and Tables 3.6 and 3.7 give the activity remaining in the lung and the total activity in the body at various times after an acute inhalation intake. Table 3.8 gives the detectable first-year effective dose equivalent for measurements performed at various times post intake.

### 3.7.2 Manganese-54

Manganese-54 ( $T_{1/2} = 312.5$  days) is the principal radioactive isotope of manganese at Hanford from an internal exposure standpoint. However, because of its relatively short effective half-life, it is usually only of minor importance in cases involving intakes of activation products. In essentially all internal exposure cases observed at Hanford that involve mixtures of

TABLE 3.4. Dose Conversion Factors for Cobalt

Site of Deposition	Target Organ <sup>(a)</sup>	<sup>58</sup> Co DCF, rem/nCi-day	<sup>60</sup> Co DCF, rem/nCi-day
Lung	Lung	4.2 E-6	1.1 E-5
	Effective	5.0 E-7	1.3 E-6
Body <sup>(b)</sup>	Gonad	2.6 E-7	7.2 E-7
	Breast	2.6 E-7	6.4 E-7
	Red marrow	2.8 E-7	6.8 E-7
	Lung	2.8 E-7	6.5 E-7
	Liver	8.0 E-7	2.0 E-6
	Effective	3.1 E-7	7.9 E-7

(a) Organ doses included for organs contributing more than 10% to the total effective dose equivalent.

(b) Excludes lung and assumes 10% in liver and 90% in the rest of the body. Factors can be applied directly to whole body count data from which the contribution due to activity in the lung has been subtracted.

TABLE 3.5. Predicted Effective Dose Equivalents Resulting from an Inhalation Intake of 1- $\mu$ m-AMAD <sup>58</sup>Co or <sup>60</sup>Co Particles

	mrem/nCi		Fraction of 50-Yr Committed Effective Dose Equivalent Received in First Year
	First-Yr Effective Dose Equivalent	50-Yr Committed Dose Equivalent	
<sup>58</sup> Co			
Class W	0.0065	0.0066	99%
Class Y	0.011	0.011	>99%
<sup>60</sup> Co			
Class W	0.028	0.034	81%
Class Y	0.080	0.22	37%

TABLE 3.6. Expected  $^{58}\text{Co}$  Activity Following an Acute Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem<sup>(a)</sup>

Days Post Intake	Activity, nCi			
	Class W		Class Y	
	Lung	Whole Body	Lung	Whole Body
7	200	260	130	140
14	170	200	120	120
30	120	140	98	100
60	60	76	71	74
90	30	42	52	50
180	3.9	7.9	19	20
365	(b)	0.5	3.0	3.0
730	(b)	(b)	(b)	(b)

(a) Intake = 1500 nCi class W or 910 nCi class Y, assuming 1- $\mu\text{m}$ -AMAD particles.

(b) Negligible.

TABLE 3.7. Expected  $^{60}\text{Co}$  Activity Following an Acute Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem<sup>(a)</sup>

Days Post Intake	Activity, nCi			
	Class W		Class Y	
	Lung	Whole Body	Lung	Whole Body
7	50	64	19	21
14	45	55	18	19
30	37	44	18	19
60	25	32	17	18
90	17	23	17	17
180	5.1	10	15	15
365	0.4	4.0	11	12
730	(b)	2.0	6.7	7.3
1825	(b)	1.0	1.9	2.0

(a) Intake = 360 nCi class W or 125 nCi class Y, assuming 1- $\mu\text{m}$ -AMAD particles.

(b) Negligible.

TABLE 3.8. Detectable Doses for In Vivo Measurement of  $^{58}\text{Co}$  and  $^{60}\text{Co}$  Following Inhalation of a 1- $\mu\text{m}$ -AMAD Aerosol (a)

Days Post Intake	First-Yr Effective Dose Equivalent, mrem/yr			
	$^{58}\text{Co}$		$^{60}\text{Co}$	
	Class W	Class Y	Class W	Class Y
7	<1	<1	<1	1
14	<1	<1	<1	2
30	<1	<1	<1	2
60	<1	<1	<1	2
90	<1	<1	1	2
180	4	2	3	2
365	60	10	8	3

(a) Based on an MDA of 3 nCi.

activation products produced in reactors, the activation product  $^{60}\text{Co}$  is the predominant radionuclide, both in terms of activity and resulting dose.

Table 3.9 provides radiological data for  $^{54}\text{Mn}$ .

According to ICRP 30, compounds of manganese are assigned the following inhalation classes:

- class W--oxides, hydroxides, halides, nitrates
- class D--all other compounds.

TABLE 3.9. Radiological Data for  $^{54}\text{Mn}$

Half-life	313 days
Annual limit on intake (a)	
Class D	810 $\mu\text{Ci}$
Class W	810 $\mu\text{Ci}$
Whole body count MDA (b)	3 nCi

(a) From ICRP 30 (1979).

(b) MDA = minimum detectable activity (from Palmer et al. 1990).

Although the transportability of manganese present in a mixture of corrosion products is likely to be influenced by the solubility, physical, and chemical characteristics of the host matrix, it is appropriate to assume in a priori dose calculations, an inhalation class W for corrosion product manganese. ICRP 30 assigns a GI tract absorption coefficient,  $f_1$ , of 0.1 for both classes of manganese.

Once manganese enters the blood stream, it is distributed to the bone surfaces, liver, and soft tissues of the body. ICRP 30 suggests that 65% of the deposited material is retained in soft tissues, including the liver, with half-lives of 4 days for half of the material and 40 days for the other half. The other 35% is retained in the bone surfaces with a half-life of 40 days. For dosimetry purposes the 40-day component is most significant; its distribution in the body is as follows:

- bone surfaces--50%
- liver--20%
- soft tissue--30%

Thus, the above distribution would pertain to  $^{54}\text{Mn}$  observed in the body (excluding lung) about 2 weeks post intake.

Table 3.10 provides DCFs (in rem/nCi-day) for  $^{54}\text{Mn}$  deposited in the lung and in systemic organs and tissues. Table 3.11 gives the predicted first-year and 50-year committed effective dose equivalent per nanocurie of intake, and Table 3.12 shows the expected activity remaining in the lung and the total activity in the body for various times after an acute inhalation intake. Table 3.4 includes the fractional total body retention following an acute class W inhalation (the most limiting ICRP 30 case).

### 3.7.3 Iron-59

Iron-59 is a relatively minor component of typical corrosion product mixtures--contributing, for example, about 10% of the activity at N Reactor. Because of its relatively short half-life (44.5 days), its relatively greater

TABLE 3.10. Dose Conversion Factors for  $^{54}\text{Mn}$

<u>Site of Deposition</u>	<u>Target Organ<sup>(a)</sup></u>	<u>DCF, rem/nCi-day</u>
Lung	Lung	2.3 E-6
	Effective	3.7 E-7
Body <sup>(b)</sup>	Gonad	8.7 E-7
	Breast	5.4 E-7
	Red marrow	3.3 E-7
	Lung	1.7 E-7
	Liver	1.5 E-7
	Effective	2.6 E-7

(a) Organ doses included for organs contributing more than 10% to the total effective dose equivalent.

(b) Excludes lung and assumes a tissue distribution of 50% bones surfaces, 20% liver, and 30% soft tissue.

TABLE 3.11. Predicted Effective Dose Equivalent Resulting from an Inhalation Intake of 1- $\mu\text{m}$ -AMAD  $^{54}\text{Mn}$  Particles

	<u>mrem/nCi</u>		<u>Fraction of 50-Yr Committed Effective Dose Equivalent Received in First Year</u>
	<u>First-Yr Effective Dose Equivalent</u>	<u>50-Yr Committed Dose Equivalent</u>	
Class D	0.0054	0.0054	100%
Class W	0.0069	0.0069	100%

transportability from the lung, and its general distribution throughout the body, it contributes less than 10% of the total effective dose equivalent in most corrosion product exposure cases.

Table 3.13 lists radiological data for  $^{59}\text{Fe}$ .

According to ICRP 30, inhalation classes are assigned to compounds of iron as follows:

TABLE 3.12. Expected  $^{54}\text{Mn}$  Activity Following an Acute Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem<sup>(a)</sup>

Days Post Intake	Activity, nCi			
	Class D		Class W	
	Lung	Whole Body	Lung	Whole Body
7	(b)	660	200	330
14	(b)	520	180	280
30	(b)	360	140	220
60	(b)	200	89	140
90	(b)	110	57	92
180	(b)	19	15	25
365	(b)	0.5	0.9	1.7

(a) Intake = 1.8  $\mu\text{Ci}$  class D or 1.4  $\mu\text{Ci}$  class W, assuming inhalation of 1- $\mu\text{m}$ -AMAD particles.

(b) Negligible.

TABLE 3.13. Radiological Data for  $^{59}\text{Fe}$

Half-life	44.5 days
Annual limit on intake <sup>(a)</sup>	
Class D	270 $\mu\text{Ci}$
Class W	540 $\mu\text{Ci}$
Whole body count MDA <sup>(b)</sup>	6 nCi

(a) From ICRP 30.

(b) MDA = minimum detectable activity (from Palmer et al. 1990).

- class W--oxides, halides, hydroxides
- class D--all other common compounds.

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. For the a priori calculation of dose from iron intakes, ICRP 30 recommends an absorption coefficient ( $f_1$ ) of 0.1 to both class D and W compounds.

Of iron entering the blood stream, the assumption of the following organ distribution is recommended:

- liver--8%
- spleen--1.3%
- rest of body--90.7%.

Regardless of the site of deposition, iron is assumed to have a biological half-life of 2000 days. Thus, the above organ distribution can be assumed to remain fixed following intake.

Table 3.14 provides DCFs (in rem/nCi-day) for  $^{59}\text{Fe}$  deposited in the lung and in systemic organs and tissues. Table 3.15 gives the predicted first-year and 50-year committed dose equivalent per nanocurie of intake, and Table 3.16 shows the expected activity remaining in the lung and the total activity in the body for various times after an acute inhalation intake.

TABLE 3.14. Dose Conversion Factors for  $^{59}\text{Fe}$

<u>Site of Deposition</u>	<u>Target Organ<sup>(a)</sup></u>	<u>DCF, rem/nCi-day</u>
Lung	Lung	8.6 E-6
	Effective	1.1 E-6
Body <sup>(b)</sup>	Gonad	3.7 E-7
	Breast	3.5 E-7
	Liver	1.0 E-6
	Spleen	1.1 E-6
	Effective	4.6 E-7

(a) Organ doses included for organs contributing more than 10% to the total effective dose equivalent.

(b) Excludes lung and assumes 8% in liver, 1.3% in spleen, and 90.7% in the rest of the body. Factors can be applied directly to whole body count data from which the contribution due to activity in the lung has been subtracted.

**TABLE 3.15.** Predicted Effective Dose Equivalent Resulting from an Inhalation Intake of 1- $\mu$ m-AMAD  $^{59}\text{Fe}$  Particles

	mrem/nCi		Fraction of 50-Yr Committed Effective Dose Equivalent Received in First Year
	First-Yr Effective Dose Equivalent	50-Yr Committed Dose Equivalent	
Class D	0.016	0.016	100%
Class W	0.013	0.013	100%

**TABLE 3.16.** Expected  $^{59}\text{Fe}$  Activity Following an Acute Intake Resulting in a First-Year Effective Dose Equivalent of 10 mrem<sup>(a)</sup>

Days Post Intake	Activity, nCi			
	Class D		Class W	
	Lung	Whole Body	Lung	Whole Body
7	(b)	280	97	180
14	(b)	250	79	160
30	(b)	190	51	110
60	(b)	120	21	64
90	(b)	74	9.2	37
180	(b)	18	0.7	8.0
365	(b)	0.9	(b)	0.4

(a) Intake = 630 nCi class D or 780 nCi class W, assuming 1- $\mu$ m-AMAD particles.

(b) Negligible.

**SECTION 4.0**

**STRONTIUM**

#### 4.0 STRONTIUM

This section summarizes the technical basis and provides some historical perspective for the internal dosimetry of strontium at Hanford.

Historically, Hanford internal dosimetry for strontium was based on estimating the long-term systemic deposition, using urine data and Dolphin's excretion model (Dolphin and Eve 1963a, 1963b), and comparing it with the 2- $\mu$ Ci ICRP 2 maximum permissible body burden (MPBB) (ICRP 1959). The long-term (formerly referred to as "permanent") deposition was defined as the amount remaining in the body at 1 year post intake, which was calculated to be 15% of the initial systemic uptake. This evaluation technique was described in several short explanations, the most recent being Appendix G of the Hanford Dosimetry Evaluation Manual (PNL-MA-575).<sup>(a)</sup> Earlier versions are listed in Table 4.1.

In April 1985, the practice of investigating all positive  $^{90}\text{Sr}$  results regardless of their dose implication was discontinued, and only results potentially indicating long-term systemic depositions in excess of 1% of the above-described level were investigated. This change in practice was made due to increased sensitivity of the analytical procedure and the indication of potential background levels in the range of the minimum detection level for the analytical procedure. Using the above model, derived investigation levels were calculated for various times post intake, and these were documented by letter to the Hanford Radiation Protection Historical Files as referenced in Table 4.1.

This technical basis incorporates the ICRP 26 and 30 (1977, 1979) concepts of tissue and effective doses, the ICRP alkaline earth model (1973) as implemented using the GENMOD computer code (Johnson and Carver 1981; see Appendix A), and supersedes the previously documented techniques for assessing internal exposure to strontium at Hanford.

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(a) Pacific Northwest Laboratory. 1982. Hanford Dosimetry Evaluation Manual. PNL-MA-575, Richland, Washington.