12.0 Iodine

Radioiodines generated or used at Hanford have included isotopes with half-lives ranging from minutes to millions of years in various physical and chemical forms. With the time that has elapsed since operation of Hanford production reactors and the FFTF, the short-lived radioiodines have all decayed away, leaving only ^{129}I as a waste contaminant. Laboratory use of short-lived radioiodines may still occur. This chapter provides information on the sources, characteristics, and biokinetics of radioiodine and summarizes the technical basis used for its internal dosimetry at Hanford.

12.1 Sources and Characteristics of Radioiodine

At Hanford the radioiodines of principal interest are ^{131}I, associated with reactor operations, ^{129}I, associated with waste management, and ^{125}I, associated with biological experimentation. Radiological decay data for these nuclides are shown in Table 12.1.

Table 12.1. Radiological Data for Radioiodines

Isotope	Half-Life	Decay Constant	Specific Activity (Ci/g)
^{131}I	8.0 d	8.7E-02 d^{-1}	1.24E+05
^{129}I	1.57E+07 y	4.4E-8 y^{-1}	1.76E-04
^{125}I	60 d	1.2E-02 d^{-1}	1.73E+04

Historically, radioiodines were generated in large quantities during the operation of production and research reactors, however with those reactors either permanently shut down or in long-term standby, the only current source of onsite fission product radioiodine at Hanford is the Energy Northwest power reactor, Columbia Generating Station. Iodine-131 is considered the most significant radioiodine from an internal exposure standpoint. Several other radioactive isotopes of iodine are generated by the fission process; however, with the exception of the long-lived ^{129}I, the others are short-lived and of potential interest only during or within several days of reactor operation. Iodine-129 has, for practical purposes, an infinite half-life and is contained in irradiated fuel and associated separations and waste management facilities. However, unless concentrated by some means such as in the PUREX air treatment system, it is present in negligibly small quantities.

The main source for ^{131}I, which has been measured in Hanford workers in recent years, has been nonoccupational medical administrations for either diagnostic or therapeutic purposes. Patients receiving such administrations lose ^{131}I by normal pathways including urine excretion and exhalation. The magnitude of medical administrations can easily result in small quantities of ^{131}I being absorbed by caregivers, family members, or those in close contact with patients, even after patients are released from a hospital.

Iodine-125 is not generated at Hanford, but it is purchased for use in various biological research experiments. Thus, its use is generally limited to biology laboratories operated by PNNL. Quantities of the isotope in use at one time are generally limited to amounts that could not result in significant internal exposures.

12.2 Biokinetic Behavior

The distribution and retention models described in ICRP 30 (1979) and ICRP 54 (1988) are used by Hanford to predict the uptake, retention, and resulting doses following an intake of a radioiodine.

12.2.1 Transportability Class

In its publication 30, the ICRP assigned inhalation class D to all forms of iodine, and this category is used for Hanford dosimetry.

A new respiratory tract model (ICRP 1994a) established lung absorption types as a replacement for the inhalation class of ICRP 30. The more recent ICRP publications 68 (1994b) and 78 (1997) assign absorption type F to all iodine compounds except elemental iodine vapor, which is assigned absorption class SR-1. The use of the SR-1 class would result in a 100% respiratory tract deposition and uptake of iodine from an inhalation intake instead of the 63% described by ICRP 30. These more recent concepts are not adopted at this time, awaiting suitable analytical tools for Hanford data analysis.

12.2.2 Gastrointestinal Uptake to Blood (f_1 Factor)

The gastrointestinal uptake (f_1) factor for all forms of iodine is 1.0. This value is the same for ICRP 30 and 54 models, and the more recent ICRP 67 (1993), 68, and 78 models.

12.2.3 Biokinetic Model

The ICRP 30 and 54 metabolic model describes the deposition and retention of iodine in systemic compartments of the body and is

essentially the same model described by Riggs (1952). Of the iodine entering the systemic compartment, a fraction, 0.3, is assumed to be translocated to the thyroid, while the remainder (0.7) is assumed to go directly to excretion. Iodine in the thyroid is assumed to be retained with a biological half-life of 80 days and to be lost from the thyroid in the form of organic iodine. Organic iodine is assumed to be uniformly distributed among all organs and tissues of the body other than the thyroid and to be retained there with a biological half-life of 12 days. One-tenth of this organic iodine is then assumed to go directly to fecal excretion and the rest is assumed to be returned to the transfer compartment as inorganic iodine. This recycling to the transfer compartment gives an effective (i.e., apparent) half-life in the thyroid of 120 days. The above model was implemented using the computer code CINDY (Strenge et al. 1992).

For simplicity, ICRP 54 (1988) provides a thyroid retention function that effectively provides expected thyroid quantities following uptake, and that can be easily incorporated into hand calculations:

$$R(t)_{thyroid} = 0.33e^{-0.693t/0.24} + 0.018e^{-0.693t/11} + 0.31e^{-0.693t/120} \qquad (12.1)$$

where t is in days post uptake.

For class D material, translocation from the lung to the blood is rapid and the above equation will provide an accurate thyroid retention value for the model after several days following acute inhalation.

12.3 Internal Dosimetry Factors for Radioiodines

This section contains factors that are useful in making internal dosimetry calculations. The factors are derived from the CINDY 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.

12.3.1 Retention and Excretion of Radioiodine

Retention and excretion fractions can be readily calculated using the CINDY code. Factors for the total body, thyroid, and urine have been calculated based on ingestion and inhalation of 1-µm- and 5-µm-AMAD particles. These factors are shown in Table 12.2 for ^{131}I, Table 12.3 for ^{129}I, and Table 12.4 for ^{125}I. Because the GI tract uptake factor is 1.0, the ingestion-based retention and excretion fractions can be used to approximate an injection (wound) intake.

Table 12.2. Retention and Excretion for ^{131}I

	Days Post Intake	Inhalation 1-mm-AMAD Class D	Inhalation 5-mm-AMAD Class D	Ingestion f_1=1
Whole Body Retention	1	2.7E-01	3.2E-01	3.2E-01
	2	1.9E-01	2.4E-01	2.6E-01
	5	1.2E-01	1.8E-01	2.0E-01
	7	1.0E-01	1.5E-01	1.7E-01
	14	5.8E-02	8.3E-02	9.1E-02
	30	1.4E-02	2.0E-02	2.2E-02
	60	9.9E-04	1.4E-03	1.6E-03
	90	6.8E-05	9.8E-05	1.1E-04
	180	2.2E-08	3.1E-08	3.5E-08
	365	3.2E-12	1.3E-12	3.2E-12
Thyroid	1	1.3E-01	2.2E-01	2.6E-01
	2	1.5E-01	2.2E-01	2.5E-01
	5	1.2E-01	1.7E-01	1.9E-01
	7	1.0E-01	1.4E-01	1.6E-01
	14	5.3E-02	7.6E-02	8.4E-02
	30	1.2E-02	1.8E-02	2.0E-02
	60	8.5E-04	1.2E-03	1.3E-03
	90	5.8E-05	8.4E-05	9.2E-05
	180	1.9E-08	2.7E-08	3.0E-08
	365	4.7E-12	1.1E-12	2.7E-12
Urine	1	1.3E-01	1.3E-01	1.3E-01
	2	3.2E-02	1.6E-02	7.4E-03
	5	7.6E-04	4.3E-04	2.3E-04
	7	2.1E-04	2.6E-04	2.7E-04
	14	1.6E-04	2.3E-04	2.6E-04
	30	6.0E-05	8.7E-05	9.6E-05
	60	5.0E-06	7.2E-06	7.9E-06
	90	3.5E-07	5.1E-07	5.6E-07
	180	1.1E-10	1.6E-10	1.8E-10
	365	1.7E-14	6.9E-15	1.7E-14

Table 12.3. Retention and Excretion for ^{129}I

	Days Post Intake	Inhalation 1-mm-AMAD Class D	Inhalation 5-mm-AMAD Class D	Ingestion f_1=1
Whole Body Retention	1	3.0E-01	3.4E-01	3.5E-01
	2	2.2E-01	2.9E-01	3.0E-01
	5	1.9E-01	2.7E-01	3.0E-01
	7	1.9E-01	2.7E-01	3.0E-01
	14	1.8E-01	2.7E-01	2.9E-01
	30	1.7E-01	2.5E-01	2.7E-01
	60	1.5E-01	2.1E-01	2.3E-01
	90	1.2E-01	1.8E-01	1.9E-01
	180	7.1E-02	1.0E-01	1.1E-01
	365	2.3E-02	3.3E-02	3.7E-02
	730	2.5E-03	3.6E-03	4.0E-03
Thyroid	1	1.4E-01	2.4E-01	2.8E-01
	2	1.7E-01	2.6E-01	2.9E-01
	5	1.8E-01	2.6E-01	2.9E-01
	7	1.8E-01	2.6E-01	2.8E-01
	14	1.7E-01	2.4E-01	2.7E-01
	30	1.5E-01	2.2E-01	2.4E-01
	60	1.3E-01	1.8E-01	2.0E-01
	90	1.0E-01	1.5E-01	1.7E-01
	180	6.2E-02	8.7E-02	9.6E-02
	365	2.0E-02	2.8E-02	3.1E-02
	730	2.1E-03	3.1E-03	3.4E-03
Urine	1	1.3E-01	1.4E-01	1.4E-01
	2	3.7E-02	1.9E-02	8.7E-03
	5	1.1E-03	6.5E-04	3.5E-04
	7	3.7E-04	4.6E-04	4.8E-04
	14	5.1E-04	7.5E-04	8.3E-04
	30	7.3E-04	1.1E-03	1.2E-03
	60	7.4E-04	1.1E-03	1.2E-03
	90	6.4E-04	9.2E-04	1.0E-03
	180	3.7E-04	5.3E-04	5.9E-04
	365	1.2E-04	1.7E-04	1.9E-04
	730	1.3E-05	1.9E-05	2.1E-05

Table 12.4. Retention and Excretion for ^{125}I

	Days Post Intake	Inhalation 1-mm-AMAD Class D	Inhalation 5-mm-AMAD Class D	Ingestion f_1=1
Whole Body Retention	1	2.9E-01	3.4E-01	3.5E-01
	2	2.1E-01	2.8E-01	3.0E-01
	5	1.8E-01	2.6E-01	2.8E-01
	7	1.7E-01	2.5E-01	2.8E-01
	14	1.6E-01	2.3E-01	2.5E-01
	30	1.2E-01	1.8E-01	1.9E-01
	60	7.3E-02	1.1E-01	1.2E-01
	90	4.4E-02	6.3E-02	6.9E-02
	180	9.0E-03	1.3E-02	1.4E-02
	365	3.5E-04	5.0E-04	5.6E-04
Thyroid	1	1.4E-01	2.4E-01	2.7E-01
	2	1.7E-01	2.6E-01	2.9E-01
	5	1.7E-01	2.5E-01	2.7E-01
	7	1.7E-01	2.4E-01	2.6E-01
	14	1.4E-01	2.1E-01	2.3E-01
	30	1.1E-01	1.6E-01	1.7E-01
	60	6.3E-02	9.1E-02	1.0E-01
	90	3.7E-02	5.4E-02	5.9E-02
	180	7.7E-03	1.1E-02	1.2E-02
	365	3.0E-04	4.3E-04	4.7E-04
Urine	1	1.4E-01	1.4E-01	1.4E-01
	2	3.6E-02	1.9E-02	8.5E-03
	5	1.1E-03	6.1E-04	3.3E-04
	7	3.4E-04	4.3E-04	4.5E-04
	14	4.4E-04	6.4E-04	7.1E-04
	30	5.2E-04	7.5E-04	8.3E-04
	60	3.7E-04	5.3E-04	5.9E-04
	90	2.3E-04	3.3E-04	3.6E-04
	180	4.7E-05	6.8E-05	7.2E-05
	365	1.8E-06	2.6E-06	2.9E-06

12.3.2 Dose Coefficients

Dose coefficients, expressed as committed dose equivalent per unit activity of intake (e.g., rem/nCi), are a convenient shortcut for estimating doses based on standard assumptions when the magnitude of an intake is known. Acute intake dose coefficients have been calculated using CINDY and are tabulated for selected exposure scenarios in Table 12.5.

Table 12.5. Committed Dose Coefficients for Radioiodines (rem/nCi)

Radionuclide	Organ	Class D Inhalation		Ingestion
		1-mm-AMAD	5-mm-AMAD	$f_1 = 1$
^{131}I	Effective	3.1E-05	4.5E-05	4.9E-05
	Thyroid	1.0E-03	1.5E-03	1.6E-03
^{129}I	Effective	1.6E-04	2.2E-04	2.5E-04
	Thyroid	5.2E-03	7.5E-03	8.2E-03
^{125}I	Effective	2.2E-05	3.2E-05	3.6E-05
	Thyroid	7.4E-04	1.1E-03	1.2E-03

The thyroid is the principally exposed organ following an intake of radioiodine and can be considered to be the only organ contributing to the effective dose equivalent for radioiodines. Because of the low weighting factor for the thyroid (w_t = 0.03), the limiting dose from a regulatory standpoint is the nonstochastic limit of 50 rem/yr.

12.3.3 Comparison of Published Dosimetry Factors

A comparison of selected dosimetry factors for ^{131}I (as the most common radioiodine) is shown in Table 12.6.

12.3.4 Derived Reference Levels

Derived reporting and investigation levels (based on committed effective dose equivalents of 10 mrem and 100 mrem, respectively) and dose limit compliance levels (based on 50 rem to the thyroid) have been derived for inhalation of class D 1-µm- and 5-µm-AMAD particles, and for ingestion. Tabulations are provided in Table 12.7 for ^{131}I, Table 12.8 for ^{129}I, and Table 12.9 for ^{125}I. Examination of these tables shows that for each of the three nuclides, the value of each bioassay considered (whole body, thyroid, urine) is similar after a few days, regardless of the type of intake. Thus, from a practical standpoint, the derived reference levels for a 1-µm inhalation, a 5-µm inhalation, and an ingestion are sufficiently close to suggest that a single value can be used for any of them. For purposes of

Table 12.6. Comparison of Dosimetric Factors for Soluble ^{131}I

Reference Source	Class D Inhalation 1-mm-AMAD	Class D Inhalation 5-mm-AMAD	Soluble Ingestion $f_1 = 1$
Dose Coefficients Effective			
CINDY [$h_{E,50}$]	3.1E-05 rem/nCi	4.5E-05 rem/nCi	4.9E-05 rem/nCi
ICRP 54 [$h_{E,50}$]	8.8E-09 Sv/Bq (3.3E-05 rem/nCi)	NA	NA
EPA Federal Guidance Report No. 11 [$h_{E,50}$]	8.89E-09 Sv/Bq (3.29E-05 rem/nCi)	NA	1.44E-08 Sv/Bq (5.33E-05 rem/nCi)
ICRP 68 [e(50)]	7.6E-09 Sv/Bq (2.8E-05 rem/nCi)	1.1E-08 Sv/Bq (4.1E-05 rem/nCi)	2.2E-08 Sv/Bq (8.1E-05 rem/nCi)
Thyroid			
CINDY [$h_{E,50}$]	1.0E-03 rem/nCi	1.5E-03 rem/nCi	1.6E-03 rem/nCi
ICRP 54 [$h_{E,50}$]	2.9E-07 Sv/Bq (1.1E-03 rem/nCi)	NA	NA
EPA Federal Guidance Report No. 11 [$h_{E,50}$]	2.92E-07 Sv/Bq (1.08E-03 rem/nCi)	NA	4.76E-07 Sv/Bq (1.76E-03 rem/nCi)
DAC (Thyroid)			
10 CFR 835, App. A	2E-08 µCi/ml and 7E+02 Bq/m^3	NA	NA
EPA Federal Guidance Report No. 11	2E-08 µCi/ml and 7E-04 MBq/m^3	NA	NA
ICRP 30, ICRP 54	7E+02 Bq/m^3	NA	NA
Annual Limit on Intake, ALI (Thyroid)			
Calculated from 10 CFR 835 DAC	48 µCi and 1.7E+06 Bq	NA	NA
ICRP 30	2E+06 Bq	NA	1E+06 Bq
EPA Federal Guidance Report No. 11	2 MBq and 50 µCi	NA	1 MBq and 30 µCi
NA = not applicable			

Table 12.7. Reference Levels and Derived Reference Levels for ^{131}I

Days Post Intake	10-mrem $H_{E,50}$ Reporting Level			100-mrem $H_{E,50}$ Investigation Level			50-mrem $H_{t,50}$ Compliance Level		
	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion
Intake (nCi)	3.2E+02	2.2E+02	2.0E+02	3.2E+03	2.2E+03	2.0E+03	5.0E+04	3.3E+04	3.1E+04
Whole Body Count Bioassay (nCi)									
1	8.7E+01	7.1E+01	6.5E+01	8.7E+02	7.1E+02	6.5E+02	1.4E+04	1.1E+04	1.0E+04
2	6.1E+01	5.3E+01	5.3E+01	6.1E+02	5.3E+02	5.3E+02	9.5E+03	8.0E+03	8.1E+03
5	3.9E+01	4.0E+01	4.1E+01	3.9E+02	4.0E+02	4.1E+02	6.0E+03	6.0E+03	6.3E+03
7	3.2E+01	3.3E+01	3.5E+01	3.2E+02	3.3E+02	3.5E+02	5.0E+03	5.0E+03	5.3E+03
14	1.9E+01	1.8E+01	1.9E+01	1.9E+02	1.8E+02	1.9E+02	2.9E+03	2.8E+03	2.8E+03
30	4.5E+00	4.4E+00	4.5E+00	4.5E+01	4.4E+01	4.5E+01	7.0E+02	6.7E+02	6.9E+02
60	3.2E-01	3.1E-01	3.3E-01	3.2E+00	3.1E+00	3.3E+00	5.0E+01	4.7E+01	5.0E+01
90	2.2E-02	2.2E-02	2.2E-02	2.2E-01	2.2E-01	2.2E-01	3.4E+00	3.3E+00	3.4E+00
180	7.1E-06	6.9E-06	7.1E-06	7.1E-05	6.9E-05	7.1E-05	1.1E-03	1.0E-03	1.1E-03
365	1.0E-09	2.9E-10	6.5E-10	1.0E-08	2.9E-09	6.5E-09	1.6E-07	4.3E-08	1.0E-07
Thyroid Count Bioassay (nCi)									
1	4.2E+01	4.9E+01	5.3E+01	4.2E+02	4.9E+02	5.3E+02	6.5E+03	7.3E+03	8.1E+03
2	4.8E+01	4.9E+01	5.1E+01	4.8E+02	4.9E+02	5.1E+02	7.5E+03	7.3E+03	7.8E+03
5	3.9E+01	3.8E+01	3.9E+01	3.9E+02	3.8E+02	3.9E+02	6.0E+03	5.7E+03	5.9E+03
7	3.2E+01	3.1E+01	3.3E+01	3.2E+02	3.1E+02	3.3E+02	5.0E+03	4.7E+03	5.0E+03
14	1.7E+01	1.7E+01	1.7E+01	1.7E+02	1.7E+02	1.7E+02	2.7E+03	2.5E+03	2.6E+03
30	3.9E+00	4.0E+00	4.1E+00	3.9E+01	4.0E+01	4.1E+01	6.0E+02	6.0E+02	6.3E+02
60	2.7E-01	2.7E-01	2.7E-01	2.7E+00	2.7E+00	2.7E+00	4.3E+01	4.0E+01	4.1E+01
90	1.9E-02	1.9E-02	1.9E-02	1.9E-01	1.9E-01	1.9E-01	2.9E+00	2.8E+00	2.9E+00
180	6.1E-06	6.0E-06	6.1E-06	6.1E-05	6.0E-05	6.1E-05	9.5E-04	9.0E-04	9.4E-04
365	1.5E-09	2.4E-10	5.5E-10	1.5E-08	2.4E-09	5.5E-09	2.4E-07	3.7E-08	8.4E-08
Urine Bioassay (dmp/d)									
1	9.3E+04	6.4E+04	5.9E+04	9.3E+05	6.4E+05	5.9E+05	1.4E+07	9.6E+06	9.0E+06
2	2.3E+04	7.9E+03	3.4E+03	2.3E+05	7.9E+04	3.4E+04	3.6E+06	1.2E+06	5.1E+05
5	5.4E+02	2.1E+02	1.0E+02	5.4E+03	2.1E+03	1.0E+03	8.4E+04	3.2E+04	1.6E+04
7	1.5E+02	1.3E+02	1.2E+02	1.5E+03	1.3E+03	1.2E+03	2.3E+04	1.9E+04	1.9E+04
14	1.1E+02	1.1E+02	1.2E+02	1.1E+03	1.1E+03	1.2E+03	1.8E+04	1.7E+04	1.8E+04
30	4.3E+01	4.3E+01	4.3E+01	4.3E+02	4.3E+02	4.3E+02	6.7E+03	6.4E+03	6.7E+03
60	3.6E+00	3.6E+00	3.6E+00	3.6E+01	3.6E+01	3.6E+01	5.6E+02	5.3E+02	5.5E+02
90	2.5E-01	2.5E-01	2.5E-01	2.5E+00	2.5E+00	2.5E+00	3.9E+01	3.8E+01	3.9E+01
180	7.9E-05	7.9E-05	8.2E-05	7.9E-04	7.9E-04	8.2E-04	1.2E-02	1.2E-02	1.2E-02
365	1.2E-08	3.4E-09	7.7E-09	1.2E-07	3.4E-08	7.7E-08	1.9E-06	5.1E-07	1.2E-06

Table 12.8. Reference Levels and Derived Reference Levels for ^{129}I

Days Post Intake	10-mrem $H_{E,50}$ Reporting Level			100-mrem $H_{E,50}$ Investigation Level			50-mrem $H_{t,50}$ Compliance Level		
	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion
Intake (nCi)	6.3E+01	4.5E+01	4.0E+01	6.3E+02	4.5E+02	4.0E+02	9.6E+03	6.7E+03	6.1E+03
Whole Body Count Bioassay (nCi)									
1	1.9E+01	1.5E+01	1.4E+01	1.9E+02	1.5E+02	1.4E+02	2.9E+03	2.3E+03	2.1E+03
2	1.4E+01	1.3E+01	1.2E+01	1.4E+02	1.3E+02	1.2E+02	2.1E+03	1.9E+03	1.8E+03
5	1.2E+01	1.2E+01	1.2E+01	1.2E+02	1.2E+02	1.2E+02	1.8E+03	1.8E+03	1.8E+03
7	1.2E+01	1.2E+01	1.2E+01	1.2E+02	1.2E+02	1.2E+02	1.8E+03	1.8E+03	1.8E+03
14	1.1E+01	1.2E+01	1.2E+01	1.1E+02	1.2E+02	1.2E+02	1.7E+03	1.8E+03	1.8E+03
30	1.1E+01	1.1E+01	1.1E+01	1.1E+02	1.1E+02	1.1E+02	1.6E+03	1.7E+03	1.6E+03
60	9.4E+00	9.5E+00	9.2E+00	9.4E+01	9.5E+01	9.2E+01	1.4E+03	1.4E+03	1.4E+03
90	7.5E+00	8.2E+00	7.6E+00	7.5E+01	8.2E+01	7.6E+01	1.2E+03	1.2E+03	1.2E+03
180	4.4E+00	4.5E+00	4.4E+00	4.4E+01	4.5E+01	4.4E+01	6.8E+02	6.7E+02	6.7E+02
365	1.4E+00	1.5E+00	1.5E+00	1.4E+01	1.5E+01	1.5E+01	2.2E+02	2.2E+02	2.3E+02
Thyroid Count Bioassay (nCi)									
1	8.8E+00	1.1E+01	1.1E+01	8.8E+01	1.1E+02	1.1E+02	1.3E+03	1.6E+03	1.7E+03
2	1.1E+01	1.2E+01	1.2E+01	1.1E+02	1.2E+02	1.2E+02	1.6E+03	1.7E+03	1.8E+03
5	1.1E+01	1.2E+01	1.2E+01	1.1E+02	1.2E+02	1.2E+02	1.7E+03	1.7E+03	1.8E+03
7	1.1E+01	1.2E+01	1.1E+01	1.1E+02	1.2E+02	1.1E+02	1.7E+03	1.7E+03	1.7E+03
14	1.1E+01	1.1E+01	1.1E+01	1.1E+02	1.1E+02	1.1E+02	1.6E+03	1.6E+03	1.6E+03
30	9.4E+00	1.0E+01	9.6E+00	9.4E+01	1.0E+02	9.6E+01	1.4E+03	1.5E+03	1.5E+03
60	8.1E+00	8.2E+00	8.0E+00	8.1E+01	8.2E+01	8.0E+01	1.3E+03	1.2E+03	1.2E+03
90	6.3E+00	6.8E+00	6.8E+00	6.3E+01	6.8E+01	6.8E+01	9.6E+02	1.0E+03	1.0E+03
180	3.8E+00	4.0E+00	3.8E+00	3.8E+01	4.0E+01	3.8E+01	5.9E+02	5.8E+02	5.9E+02
365	1.3E+00	1.3E+00	1.2E+00	1.3E+01	1.3E+01	1.2E+01	1.9E+02	1.9E+02	1.9E+02
Urine Bioassay (dmp/d)									
1	1.9E+04	1.4E+04	1.2E+04	1.9E+05	1.4E+05	1.2E+05	3.0E+06	2.1E+06	1.9E+06
2	5.1E+03	1.9E+03	7.7E+02	5.1E+04	1.9E+04	7.7E+03	7.9E+05	2.8E+05	1.2E+05
5	1.5E+02	6.6E+01	3.1E+01	1.5E+03	6.6E+02	3.1E+02	2.3E+04	9.6E+03	4.7E+03
7	5.1E+01	4.6E+01	4.3E+01	5.1E+02	4.6E+02	4.3E+02	7.9E+03	6.8E+03	6.5E+03
14	7.1E+01	7.6E+01	7.4E+01	7.1E+02	7.6E+02	7.4E+02	1.1E+04	1.1E+04	1.1E+04
30	1.0E+02	1.1E+02	1.1E+02	1.0E+03	1.1E+03	1.1E+03	1.6E+04	1.6E+04	1.6E+04
60	1.0E+02	1.1E+02	1.1E+02	1.0E+03	1.1E+03	1.1E+03	1.6E+04	1.6E+04	1.6E+04
90	8.9E+01	9.3E+01	8.9E+01	8.9E+02	9.3E+02	8.9E+02	1.4E+04	1.4E+04	1.4E+04
180	5.1E+01	5.3E+01	5.2E+01	5.1E+02	5.3E+02	5.2E+02	7.9E+03	7.8E+03	8.0E+03
365	1.7E+01	1.7E+01	1.7E+01	1.7E+02	1.7E+02	1.7E+02	2.6E+03	2.5E+03	2.6E+03

Table 12.9. Reference Levels and Derived Reference Levels for ^{125}I

Days Post Intake	10-mrem $H_{E,50}$ Reporting Level			100-mrem $H_{E,50}$ Investigation Level			50-mrem $H_{t,50}$ Compliance Level		
	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion	1-mm Inhalation	5-mm Inhalation	Ingestion
Intake (nCi)	4.5E+02	3.1E+02	2.8E+02	4.5E+03	3.1E+03	2.8E+03	6.8E+04	4.5E+04	4.2E+04
Whole Body Count Bioassay (nCi)									
1	1.3E+02	1.1E+02	9.7E+01	1.3E+03	1.1E+03	9.7E+02	2.0E+04	1.5E+04	1.5E+04
2	9.5E+01	8.8E+01	8.3E+01	9.5E+02	8.8E+02	8.3E+02	1.4E+04	1.3E+04	1.3E+04
5	8.2E+01	8.1E+01	7.8E+01	8.2E+02	8.1E+02	7.8E+02	1.2E+04	1.2E+04	1.2E+04
7	7.7E+01	7.8E+01	7.8E+01	7.7E+02	7.8E+02	7.8E+02	1.1E+04	1.1E+04	1.2E+04
14	7.3E+01	7.2E+01	6.9E+01	7.3E+02	7.2E+02	6.9E+02	1.1E+04	1.0E+04	1.0E+04
30	5.5E+01	5.6E+01	5.3E+01	5.5E+02	5.6E+02	5.3E+02	8.1E+03	8.2E+03	7.9E+03
60	3.3E+01	3.4E+01	3.3E+01	3.3E+02	3.4E+02	3.3E+02	4.9E+03	5.0E+03	5.0E+03
90	2.0E+01	2.0E+01	1.9E+01	2.0E+02	2.0E+02	1.9E+02	3.0E+03	2.9E+03	2.9E+03
180	4.1E+00	4.1E+00	3.9E+00	4.1E+01	4.1E+01	3.9E+01	6.1E+02	5.9E+02	5.8E+02
365	1.6E-01	1.6E-01	1.6E-01	1.6E+00	1.6E+00	1.6E+00	2.4E+01	2.3E+01	2.3E+01
Thyroid Count Bioassay (nCi)									
1	6.4E+01	7.5E+01	7.5E+01	6.4E+02	7.5E+02	7.5E+02	9.5E+03	1.1E+04	1.1E+04
2	7.7E+01	8.1E+01	8.1E+01	7.7E+02	8.1E+02	8.1E+02	1.1E+04	1.2E+04	1.2E+04
5	7.7E+01	7.8E+01	7.5E+01	7.7E+02	7.8E+02	7.5E+02	1.1E+04	1.1E+04	1.1E+04
7	7.7E+01	7.5E+01	7.2E+01	7.7E+02	7.5E+02	7.2E+02	1.1E+04	1.1E+04	1.1E+04
14	6.4E+01	6.6E+01	6.4E+01	6.4E+02	6.6E+02	6.4E+02	9.5E+03	9.5E+03	9.6E+03
30	5.0E+01	5.0E+01	4.7E+01	5.0E+02	5.0E+02	4.7E+02	7.4E+03	7.3E+03	7.1E+03
60	2.9E+01	2.8E+01	2.8E+01	2.9E+02	2.8E+02	2.8E+02	4.3E+03	4.1E+03	4.2E+03
90	1.7E+01	1.7E+01	1.6E+01	1.7E+02	1.7E+02	1.6E+02	2.5E+03	2.5E+03	2.5E+03
180	3.5E+00	3.4E+00	3.3E+00	3.5E+01	3.4E+01	3.3E+01	5.2E+02	5.0E+02	5.0E+02
365	1.4E-01	1.3E-01	1.3E-01	1.4E+00	1.3E+00	1.3E+00	2.0E+01	2.0E+01	2.0E+01
Urine Bioassay (dmp/d)									
1	1.4E+05	9.7E+04	8.6E+04	1.4E+06	9.7E+05	8.6E+05	2.1E+07	1.4E+07	1.3E+07
2	3.6E+04	1.3E+04	5.2E+03	3.6E+05	1.3E+05	5.2E+04	5.4E+06	1.9E+06	7.9E+05
5	1.1E+03	4.2E+02	2.0E+02	1.1E+04	4.2E+03	2.0E+03	1.7E+05	6.2E+04	3.1E+04
7	3.4E+02	3.0E+02	2.8E+02	3.4E+03	3.0E+03	2.8E+03	5.1E+04	4.3E+04	4.2E+04
14	4.4E+02	4.4E+02	4.4E+02	4.4E+03	4.4E+03	4.4E+03	6.6E+04	6.5E+04	6.6E+04
30	5.4E+02	5.2E+02	5.1E+02	5.4E+03	5.2E+03	5.1E+03	8.1E+04	7.6E+04	7.7E+04
60	3.7E+02	3.7E+02	3.6E+02	3.7E+03	3.7E+03	3.6E+03	5.6E+04	5.3E+04	5.5E+04
90	2.3E+02	2.3E+02	2.2E+02	2.3E+03	2.3E+03	2.2E+03	3.5E+04	3.3E+04	3.3E+04
180	4.7E+01	4.7E+01	4.4E+01	4.7E+02	4.7E+02	4.4E+02	7.1E+03	6.9E+03	6.7E+03
365	1.8E+00	1.8E+00	1.8E+00	1.8E+01	1.8E+01	1.8E+01	2.7E+02	2.6E+02	2.7E+02

bioassay program design and data evaluation, the 5-µm inhalation-derived reference levels are used at Hanford as a standard against which routine monitoring data can be compared. The choice of the 5-µm inhalation was made in large part based on the use of 5-µm-AMAD particle sizes for most aerosols at Hanford, and as a reasonable compromise between values for 1-µm-AMAD particles and ingestion.

A point of interest regarding ^{129}I is that the mass of pure ^{129}I corresponding to a compliance level intake of 6,100 nCi (i.e., the whole body retention at time zero) is 34 mg, which exceeds the iodine mass of 12 mg contained in the Reference Man total body (ICRP 1975). Thus, it is likely that a retained intake of ^{129}I, which might result in a dose exceeding the 50-rem thyroid dose limit, is physiologically impossible. This does not hold true for the short half-life radioiodines.

12.4 Bioassay for Radioiodines

In vivo measurements and a routine monitoring program for radioiodine isotopes are the main bioassay considerations.

12.4.1 Bioassay Methods and Capabilities

Radioiodine isotopes can be easily detected by in vivo measurements. Iodine-131 can be readily detected using the NaI-detector-based preview counter or the coaxial germanium detector system. However, because these are not nuclides in routine use at Hanford, they are not part of the standard library of nuclides for which in vivo measurement results are routinely calculated. The spectrum peak search routine, performed for each measurement, will find them if they are present above the peak search MDA, which is less sensitive than the library search MDA. Nominal ^{131}I MDA values for the peak search routine are about 15 nCi for the preview counter and about 2 nCi for the coaxial system.

Because of their low-energy photon emissions, ^{125}I and ^{129}I can only be measured using the intrinsic germanium (IG) detector systems in the thyroid-counting configuration. Nominal MDAs for thyroid counting are 0.1 nCi for ^{131}I and 0.8 nCi for ^{125}I and ^{129}I.

The minimum detectable intakes and associated minimum detectable doses (committed effective dose equivalents) based on the nominal MDAs are shown in Table 12.10 for ^{131}I and Table 12.11 for ^{129}I and ^{125}I.

Table 12.10. ^{131}I Minimum Detectable Intakes and Doses ($H_{E,50}$ and Thyroid $H_{T,50}$) for 5-µm-AMAD Class D Inhalation

Days Post Intake	NaI System[(a)] Minimum Detectable			Coax Ge System[(b)] Minimum Detectable			Planar Ge System[(c)] Minimum Detectable		
	Intake (nCi)	$H_{E,50}$ (mrem)	$H_{T,50}$ (mrem)	Intake (nCi)	$H_{E,50}$ (mrem)	$H_{T,50}$ (mrem)	Intake (nCi)	$H_{E,50}$ (mrem)	$H_{T,50}$ (mrem)
1	4.7E+01	2.1	70	6.3E+00	0.3	9.4	4.5E-01	0.02	0.7
2	6.3E+01	2.8	94	8.3E+00	0.4	13	4.5E-01	0.02	0.7
5	8.3E+01	3.8	130	1.1E+01	0.5	17	5.9E-01	0.03	0.9
7	1.0E+02	4.5	150	1.3E+01	0.6	20	7.1E-01	0.03	1.1
14	1.8E+02	8.1	270	2.4E+01	1.1	36	1.3E+00	0.06	2.0
30	7.5E+02	34	1100	1.0E+02	4.5	150	5.6E+00	0.25	8.3
60	1.1E+04	4.8E+02	1.6E+04	1.4E+03	64	2100	8.3E+01	3.8	130
90	1.5E+05	6.9E+03	2.3E+05	2.0E+04	9.2E+02	3.1E+04	1.2E+03	54	1800
180	4.8E+08	2.2E+07	7.3E+08	6.5E+07	2.9E+06	9.7E+07	3.7E+06	1.7E+05	5.6E+06

(a) Based on MDA of 15 nCi, whole body count
(b) Based on MDA of 2 nCi, whole body count
(c) Based on MDA of 0.1 nCi, thyroid count

Table 12.11. ^{129}I and ^{125}I Minimum Detectable Intakes and Doses ($H_{E,50}$ and Thyroid $H_{T,50}$) for 5-µm-AMAD Class D Inhalation

Days Post Intake	Iodine-129 Minimum Detectable			Iodine-125 Minimum Detectable		
	Intake (nCi)	$H_{E,50}$ (mrem)	$H_{T,50}$ (mrem)	Intake (nCi)	$H_{E,50}$ (mrem)	$H_{T,50}$ (mrem)
1	3.3	0.73	25	3.3	0.11	3.7
2	3.1	0.68	23	3.1	0.10	3.4
5	3.1	0.68	23	3.2	0.10	3.5
7	3.1	0.68	23	3.3	0.11	3.7
14	3.3	0.73	25	3.8	0.12	4.2
30	3.6	0.80	27	5.0	0.16	5.5
60	4.4	1.0	33	8.8	0.28	9.7
90	5.3	1.2	40	15	0.47	16
180	9	2.0	69	73	2.3	80
365	29	6.3	210	1900	60	2000
730	2100	84.0	2900	NA	NA	NA

(a) Based on MDA of 0.8 nCi for planar germanium system thyroid count
NA = not applicable.

Radioiodine bioassay programs at Hanford are based on in vivo measurements. Urine sample analysis using a gamma spectrum analysis protocol (Hanford MDA of 10 dpm/l) can also be used for radioiodines. However, the ease and convenience of in vivo measurements at Hanford makes urinalysis the less preferred method.

12.4.2 Routine Bioassay Monitoring Protocol

It is recommended that routine bioassay measurements be performed at intervals not exceeding four to five effective half-lives of the radionuclide because of uncertainties associated with the assumed retention characteristics. Based on that recommendation and the minimum detectable doses listed in Tables 12.10 and 12.11, the measurement frequency for the minimum recommended routine monitoring program for workers potentially exposed to ^{131}I, ^{125}I, or ^{129}I, is monthly, semiannually, and annually, respectively. If the coaxial germanium system is used for ^{131}I bioassay, bimonthly measurements (i.e., every 2 months) provide adequate sensitivity.

A supplemental approach to routine bioassay monitoring for radioiodines is to perform a workplace thyroid screening measurement shortly after completion of the iodine-related work. If there is any indication of radioiodine detection, then a more timely thyroid count can be performed using the high-resolution systems.

If a radioiodine isotope is detected in a routine measurement, follow-up measurements to confirm the intake should be performed. The measurements should preferably be performed immediately following the initial measurement while the subject is at the whole body counting facility. The use of the high-resolution germanium detectors for follow-up measurements is preferred in order to accurately quantify the thyroid deposition.

12.4.3 Special Monitoring for Suspected Intakes

Thyroid counts should be performed to assess the significance of an acute intake of radioiodine. The deposition of iodine in the thyroid following an acute intake is not instantaneous; rather, buildup of iodine in the thyroid will occur over a period of about 3 days following the intake. Results of thyroid counts obtained within a day or so of an intake may thus underestimate the maximum retained quantity that will be achieved following the exposure. Measurements made 2 to 3 days post intake will likely provide the best indication of the maximum retained quantity in the thyroid from the intake.

If significant quantities of short-lived radioiodines are possibly associated with an exposure, then in vivo measurements should be performed within a day of the intake. The measurements should be made using a germanium detector to achieve optimum resolution. Follow-up counts, if needed, should be performed. Data from facility monitoring may be used to identify the relative activities of the various radioiodines present at the time of intake. Caution should be exercised when analyzing in vivo data for short-lived iodine isotopes to ensure that activity within the thyroid and not external contamination is being measured.

12.5 Assessment of Internal Dose

Radioiodines can be detected and quantified in the thyroid using in vivo techniques. Measurement of ^{125}I and ^{129}I requires the use of the planar germanium counting system for thyroid counting. Thyroid counts are sufficiently sensitive to enable detection of activity in the thyroid at levels below that of any dosimetric consequence (see Tables 12.10 and 12.11). Thus, dose-based screening levels for thyroid assessments may be appropriate (e.g., a screening level based on 10-mrem committed effective dose equivalent provides assurance that significant doses do not go unassessed). Routine whole body counting or thyroid counting can be used for ^{131}I.

Several methods exist to evaluate in vivo results 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 low, involves fitting the in vivo measurement data to the expected internal activity using the biokinetic model prescribed in this chapter. Data-fitting is performed using CINDY. Alternatively, a hand calculation can be performed using the factors tabulated in this chapter.

Assumptions that are used for this evaluation are that 1) the material is inhaled in class D form, 2) the intake date, if unknown, is assumed to be the midpoint of the period during which the intake could have occurred, and 3) the intake consisted of the inhalation of an aerosol with an AMAD of 5 μm. Observed in vivo retention should be used in place of the ICRP biokinetic model for evaluations of internal doses that potentially exceed a 100-mrem committed effective dose equivalent when sufficient in vivo data are available for such an analysis.

12.6 Management of Internal Contamination Cases

In an accident exposure situation, iodine will likely be taken in by inhalation, ingestion, and absorption through the skin. If the iodine is very soluble, it will reach the thyroid relatively quickly; however, maximum thyroid activity may not occur until 2 or 3 days post intake. Thus, thyroid counts performed shortly after intake may underestimate the maximum deposition. Also of concern for in vivo measurements made shortly after intake are contributions to the count from radioiodine located outside the body or in other regions of the body. However, if thyroid measurements are made with a collimated germanium detector, these interferences can most likely be reduced to negligible levels.

The adult thyroid gland is considered to be a relatively radioresistant organ (weighting factor = 0.03) with respect to the risk of fatal malignancies. However, thyroid nodules, cancer, and hypothyroidism are all associated with radiation exposure to the thyroid. The intervention therapy recommended by both NCRP Report 65 (1980) and Bhattacharyya et al. (1992) is immediate administration of 300-mg KI or NaI tablets, regardless of the route of exposure, and daily administrations for 7 to 14 days (to prevent recycling back into the thyroid) as a mitigative action following a large intake. For individuals receiving greater than a 100-rem dose equivalent to the thyroid, an estimate of residual thyroid function should be made within 2 or 3 months after exposure (NCRP 1980). Occupational Medicine (at HEHF) should be immediately notified of a potentially severe intake of radioiodine.

12.7 References

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