OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SCIENTIFIC ANALYSIS COVER SHEET

1. QA: QA

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2. Scientific Analyses Title	
Characteristics of the Receptor for the Biosphere Model	
3. DI (including Revision Number)	
ANL-MGR-MD-000005 REV 02	
4. Total Attachments: 3	5. Attachment Numbers - Number of pages in each: I - 8 pages, II - 43 pages, III - 2 pages + CD-ROM

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11. Remarks

This report addesses technical error identified in TER-02-0053.

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Revision History

12. Revision/ICN No.	13. Description of Revision/Change
REV 00 ICN 00	Initial issue
REV 01 ICN 00	Revised to adopt change in approach from "logic-based" identification of the critical group to "dose-based" identification of the critical group. Added assumptions and data for time spent outdoors due to employment and
REV 01 ICN 01	- Revised to remove To Be Verified (TBVs) numbered 4636, 3958 and 4654 from the Document Input Reference System (DIRS) report assigned Data Tracking Numbers (DTNs) MO9806MWDGENII.000,
REV 02 ICN 00	Revised to change the receptor from an average member of the critical group to the reasonably maximally exposed individual (RMEI) and to develop receptor-related input parameters for the updated biosphere model

Addendum 1
recreation. Developed and used radionuclide-specific behavioral factors expessed in total effective dose equivalent per unit activity (rem/year per pCi/L) to distinguish between combinations of behaviors and to identify the critical group.

Addendum 2
MO0002RIB00068, MO0004ROB00085, MO0010SPAPET07.004.
- Identify the technical work plan (TWP) this ICN is initiated under Section 1.
- Remove sentence from Section 4.1 regarding survey data.
- Drmove DTN MO9806MWDGENII.000 from Tables 2 and I-1. Identify DTN MO9806MWDGENII.000 as an assumption in Section 5.4
- Remove URNs where applicable in Section 8.
- Remove reference to "Plan for Qualification of Unqualified Data" from 1997 Biosphere Food Consumption Survey.
- Update accession numbers in Section 8, where previously missing.
- Update DTNs MO0002RIB00068.000, MO0004RIB00085 to Qualified Data and MO0010SPAPET07.004 to Technocal Product Output in the DIRS report.
- Changes are indicated by change bars.
- THe following pages were affected by this ICN 1-2, 9-10, 12-13, 15, 18, 21, 24-26, 28, 30, 32-33, 36-38, 40, 53-58, I-1, I-2, I-4, I-5.
- Section affected, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0.
- Software routines were not developed for this model and hence, software routine data were not developed or modified as a part of this ICN.

Addendum 3
using the GoldSim platform. The entire analysis documentation was revised.

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TABLES

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ACRONYMS AND ABBREVIATIONS

AMAD	activity median aerodynamic diameter
CADI	contingent average daily (food) intake
CEDE	committed effective dose equivalent
DCF	dose conversion factor
EDE	effective dose equivalent
EPA	Environmental Protection Agency
FEP	features, events, and processes
FGR	Federal Guidance Report
GM	geometric mean
GSD	geometric standard deviation
ICRP	International Commission on Radiological Protection
LA	License Application
NCRP	National Council on Radiation Protection and Measurements
NHAPS	National Human Activity Pattern Survey
NRC	Nuclear Regulatory Commission
PAEC	potential alpha energy concentration
RMEI	reasonably maximally exposed individual
SE	standard error
TEDE	total effective dose equivalent
TSPA	total system performance assessment
TWP	technical work plan
USDA	U.S. Department of Agriculture

1. PURPOSE

This analysis report is one of the technical reports containing documentation of the Environmental Radiation Model for Yucca Mountain Nevada (ERMYN), a biosphere model supporting the Total System Performance Assessment (TSPA) for the geologic repository at Yucca Mountain. A graphical representation of the documentation hierarchy for the ERMYN is presented in Figure 1-1. This figure shows relationships among the products (i.e., analysis and model reports) developed for biosphere modeling and biosphere abstraction products for TSPA, as identified in the *Technical Work Plan: for Biosphere Modeling and Expert Support* (TWP) (BSC 2003 [163602]). Some documents identified in Figure 1-1 may be under development and not available at the time this report is issued. This figure is included to provide an understanding of how this analysis report contributes to biosphere modeling in support of the license application, and access to the listed documents is not required to understand the contents of this report. This report is one of the reports that develop input parameter values for the biosphere model. The *Biosphere Model Report* (BSC 2003 [160699]), describes the conceptual model as well as the mathematical model and its input parameters.

The purpose of this analysis report is to define values for biosphere model parameters that are related to the dietary, lifestyle, and dosimetric characteristics of the receptor. The biosphere model, consistent with the licensing rule at 10 CFR Part 63 [156605], uses a hypothetical person called the reasonably maximally exposed individual (RMEI) to represent the potentially exposed population. The parameters that define the RMEI are based on the behaviors and characteristics of the Amargosa Valley population, consistent with the requirements of 10 CFR 63.312 [156605]. Amargosa Valley is the community, located in the direction of the projected groundwater flow path, where most of the farming in the area occurs. The parameter values developed in this report support the biosphere model and are reflected in the TSPA through the biosphere dose conversion factors (BDCFs). The analysis was performed in accordance with the TWP (BSC 2003 [163602]).

This analysis supports the treatment of fourteen features, events, and processes (FEPs) applicable to the reference biosphere (DTN: MO0303SEPFEPS2.000 [162452]) and addressed in the biosphere model (BSC 2003 [160699]). The treatment of these FEPs in the biosphere model is described in the *Biosphere Model Report* (BSC 2003 [160699], Section 6.2). The parameters developed in this report and the related FEPs are listed in Table 1-1.

Biosphere modeling focuses on radionuclides screened for the TSPA-License Application (LA) (BSC 2002 [160059]). The same list of radionuclides is used in this analysis (Section 6.5.1). The analysis includes consideration of two human exposure scenarios: groundwater and volcanic ash. For the groundwater exposure scenario, radionuclides enter the biosphere from a well that extracts contaminated groundwater from an aquifer. Human exposure arises from using the contaminated water for domestic and agricultural purposes. The groundwater scenario applies to the TSPA-LA modeling cases that consider groundwater release of radionuclides from the repository at Yucca Mountain. The nominal scenario class and some modeling cases from the disruptive scenario classes (i.e., igneous intrusion or human intrusion) may result in the release of radionuclides to groundwater. For the volcanic ash scenario, the mode of radionuclide release

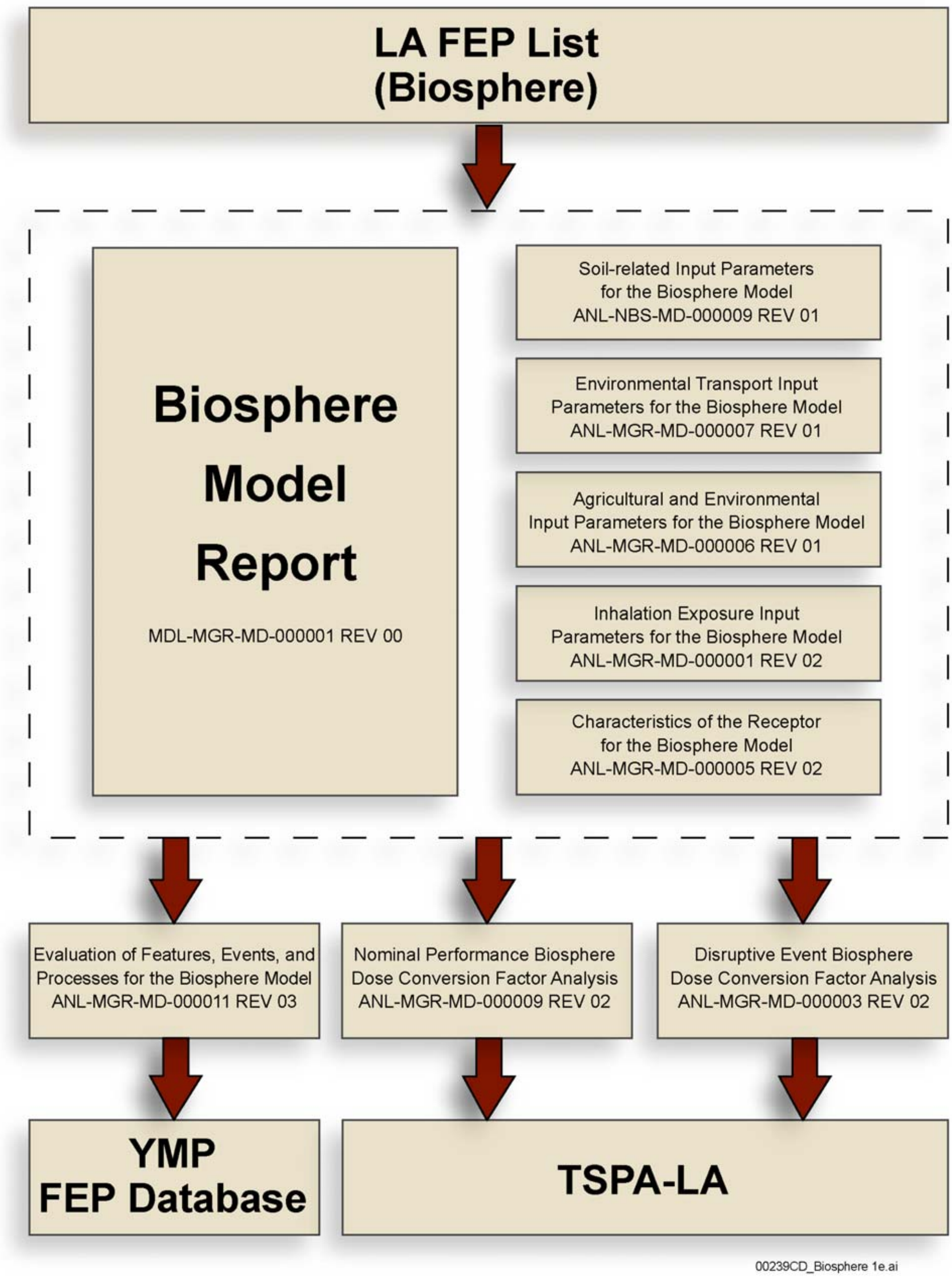


Figure 1-1. Biosphere Model Documentation

Table 1-1. Parameters and Included Features Events and Processes

Parameter(s)	FEP [a]	YMP FEP Number [a]	Associated Submodel(s)	Summary of Disposition [b]
Proportion of population by population group	Human lifestyle	2.4.04.01.0A	External exposure, Inhalation	The treatment of this parameter is described in Section 6.3.1 and summarized in Table 6.3-4.
	Inhalation	3.3.04.02.0A		
	External exposure	3.3.04.03.0A		
Annual exposure time by population group and environment	External exposure	3.3.04.03.0A	External exposure, Inhalation	The treatment of this parameter is described in Section 6.3.2 and summarized in Table 6.3-8.
	Human lifestyle	2.4.04.01.0A		
	Wild and Natural Land and Water Use	2.4.08.00.0A		
	Agricultural land use and irrigation	2.4.09.01.0B		
	Urban and Industrial Land and Water Use	2.4.10.00.0A		
	Inhalation	3.3.04.02.0A		
Breathing rate by environment and population group	Human characteristics (physiology, metabolism)	2.4.01.00.0A	Inhalation	The treatment of this parameter is described in Section 6.3.3 and summarized in Table 6.3-14.
	Inhalation	3.3.04.02.0A		
Fraction of houses with evaporative coolers	Dwellings	2.4.07.00.0A	Inhalation	The treatment of this parameter is described in Section 6.3.4.1.
	Inhalation	3.3.04.02.0A		
Evaporative cooler use factor by climate	Climate change-global	1.3.01.00.0A	Inhalation	The treatment of this parameter is described in Section 6.3.4.2.
	Biosphere characteristics	2.3.13.01.0A		
	Dwellings	2.4.07.00.0A		
	Inhalation	3.3.04.02.0A		
Annual consumption rate of locally produced food (including water) by food type	Contaminated drinking water, foodstuffs and drugs	3.3.01.00.0A	Ingestion	The treatment of this parameter is described in Section 6.4.2 and summarized in Table 6.4-2.
	Wild and Natural Land and Water Use	2.4.08.00.0A		
	Ingestion	3.3.04.01.0A		
Annual inadvertent soil ingestion rate	Contaminated drinking water, foodstuffs and drugs	3.3.01.00.0A	Ingestion	The treatment of this parameter is described in Section 6.4.3.
	Ingestion	3.3.04.01.0A		
Radionuclide half-lives and branching fractions	Radioactive decay and in-growth	3.1.01.01.0A	Inhalation, Ingestion, External Exposure	The treatment of this parameter is described in Section 6.5.1 and summarized in Table 6.5-1.

Table 1-2. Parameters and Included Features Events and Processes (continued)

Parameter(s)	FEP [a]	YMP FEP Number [a]	Associated Submodel(s)	Summary of Disposition [b]
Dose conversion factors for inhalation by radionuclide	Human characteristics (physiology, metabolism)	2.4.01.00.0A	Inhalation	The treatment of this parameter is described in Section 6.5.3.1 and summarized in Table 6.5-2.
	Inhalation	3.3.04.02.0A		
	Radioactive decay and in-growth	3.1.01.01.0A		
Dose conversion factors for ingestion by radionuclide	Human characteristics (physiology, metabolism)	2.4.01.00.0A	Ingestion	The treatment of this parameter is described in Section 6.5.3.1 and summarized in Table 6.5-2.
	Ingestion	3.3.04.01.0A		
	Radioactive decay and in-growth	3.1.01.01.0A		
Dose coefficient for exposure to contaminated ground surface by radionuclide	Human characteristics (physiology, metabolism)	2.4.01.00.0A	External exposure	The treatment of this parameter is described in Section 6.5.3.2 and summarized in Table 6.5-3.
	External exposure	3.3.04.03.0A		
	Radioactive decay and in-growth	3.1.01.01.0A		
Dose coefficient for exposure to soil contaminated to an infinite depth by radionuclide	Human characteristics (physiology, metabolism)	2.4.01.00.0A	External exposure	The treatment of this parameter is described in Section 6.5.3.2 and summarized in Table 6.5-3.
	External exposure	3.3.04.03.0A		
	Radioactive decay and in-growth	3.1.01.01.0A		
Dose conversion factor for inhalation of radon decay products	Human characteristics (physiology, metabolism)	2.4.01.00.0A	Inhalation	The treatment of this parameter is described in Section 6.5.4.
	Inhalation	3.3.04.02.0A		
	Radioactive decay and in-growth	3.1.01.01.0A		
	Radon and radon daughter exposure	3.3.08.00.0A		
Building shielding factor by radionuclide	Dwellings	2.4.07.00.0A	External exposure	The treatment of this parameter is described in Section 6.6 and summarized in Table 6.6-1.
	External exposure	3.3.04.03.0A		

NOTES: [a] Features, events, and processes are listed in DTN: MO0303SEPFEPS2.000 [162452]; YMP = Yucca Mountain Project

[b] The effects of the related FEPs are included in the TSPA through the BDCFs. See BSC (2003 [160699], Section 6.2) for a complete description of the inclusion and treatment of FEPs in the biosphere model.

into the biosphere is a volcanic eruption through the repository with the resulting entrainment of contaminated waste in the tephra and the subsequent atmospheric transport and dispersion of contaminated material in the biosphere. This scenario applies to the volcanic eruption modeling case of the igneous scenario class (BSC 2002 [160146], pp. 47 to 48), which is one of the TSPA disruptive scenario classes.

The work scope of this analysis includes development of the values of shielding factors for external exposure while indoors.

This analysis is a revision of the analysis report *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (BSC 2001 [160255]). The report was revised because the representation of the receptor in the applicable rule (10 CFR Part 63 [156605]) was changed from an average member of the critical group to the reasonably maximally exposed individual (RMEI). Another reason for revision was the development of the new biosphere model, ERMYN, which requires a redefined set of input parameters.

2. QUALITY ASSURANCE

Development of this report involves analysis of data to support performance assessment as identified in the TWP (BSC 2003 [163602]) and thus is a quality affecting activity in accordance with AP-2.27Q, *Planning for Science Activities* [159604]. Approved quality assurance procedures identified in the TWP (BSC 2003 [163602], Section 4) have been used to conduct and document the activities described in this report. Electronic data used in this analysis were controlled in accordance with the methods specified in the TWP (BSC 2003 [163602], Section 8).

The natural barriers and items identified in the *Q-List* (YMP 2001 [154817]) are not pertinent to this analysis.

3. USE OF SOFTWARE

The only software used during this analysis was the commercial off-the-shelf product Excel (Version 97 SR-2). Standard Excel functions were used to calculate parameter values, as described in the attachments to this document, and to produce histograms shown in Section 6 of this report. Use of the Excel functions, including formulas or algorithms, inputs, and outputs are described in the attachments.

4. INPUTS

4.1 DATA AND PARAMETERS

The list of parameters related to the characteristics of the receptor for the biosphere model addressed in this analysis and the sources of direct input used to develop the parameter values are shown in Table 4-1. Descriptions of the direct input follow the same order in which the parameters appear in Table 4-1.

Table 4.1-1. Biosphere Model Input Parameters Developed in this Analysis Report and the Sources of Data

Parameter	Sources of Direct Input
Proportion of population by population group	Bureau of the Census 2002 [159728]
Annual exposure time by population group and environment	Bureau of the Census 2002 [159728]
	EPA 1997, [116135] Klepeis et al. 1996 [159299] Lide and Frederikse 1997 [103178]
Breathing rate by environment and population group	ICRP 1994 [153705]
	Bureau of the Census 2002 [159728]
Fraction of houses with evaporative coolers	DTN: MO0106SPAECL02.016 [160256] Estimated Consumption of Locally Produced Food for 1,499 Respondents in Nye and Lincoln Counties
Evaporative cooler use factor by climate	DTN: MO9905VMMDJM94.000 [150068] Validated Meteorological Monitoring Data, January - March 1994
	DTN: MO9905VMMDAJ94.000 [150133] Validated Meteorological Monitoring Data, April - June 1994
	DTN: MO9905VMMDJS94.000 [150134] Validated Meteorological Monitoring Data, July - September 1994
	DTN: MO9905VMMDOD94.000 [150137] Validated Meteorological Monitoring Data, October - December 1994
	DTN: TM000000000001.065 [161051] Validated Meteorological Data, January - March 1995
	DTN: TM000000000001.068 [161050] Validated Meteorological Data, April - June 1995
	DTN: TM000000000001.071 [161049] Validated Meteorological Data, July - September 1995
	DTN: TM000000000001.077 [152925] Validated Meteorological Data, October - December 1995
	DTN: MO9903VALMM961.000 [150063] Validated Meteorological Monitoring Data, January-March 1996
	DTN: MO9903VALMM962.000 [150132] Validated Meteorological Monitoring Data, April-June 1996
	DTN: MO9903VALMM963.000 [150130] Validated Meteorological Monitoring Data, July-September 1996
	DTN: MO9903VALMM964.000 [150131] Validated Meteorological Monitoring Data, October-December 1996
	DTN: TM000000000001.100 [135874] Validated Meteorological Data, January - March 1997
	DTN: TM000000000001.104 [135876] Validated Meteorological Data, April - June 1997

Table 4.1-1. Biosphere Model Input Parameters Developed in this Analysis Report and the Sources of Data (continued)

Parameter	Sources of Direct Input
Evaporative cooler use factor by climate (continued)	DTN: TM000000000001.107 [135878] Validated Meteorological Data, July - September 1997
	DTN: MO98METDATA110.000 [135880] Validated Meteorological Data, October - December, 1997
	National Climatic Data Center [n.d.] [161091]
Annual consumption rate of locally produced food (including water) by food type	DTN: MO0010SPANYE00.001 [154976] Cleaned Nye County Food Consumption Frequency Survey
	USDA 2000 [154158]
	Bureau of the Census 2002 [159728]
	10 CFR Part 63 [156605]
Annual inadvertent soil ingestion rate	EPA 1997 [103038] Simon 1998 [160098] Stanek et al. 1997 [160251]
Radionuclide half-lives and branching fractions	Eckerman and Ryman 1993 [107684] Lide and Frederikse 1997 [103178]
Dose conversion factor for inhalation by radionuclide	Eckerman et al. 1988 [101069]
Dose conversion factor for ingestion by radionuclide	Eckerman et al. 1988 [101069]
Dose coefficient for exposure to contaminated ground surface by radionuclide	Eckerman and Ryman 1993 [107684]
Dose coefficient for exposure to soil contaminated to an infinite depth by radionuclide	Eckerman and Ryman 1993 [107684]
Dose conversion factor for inhalation of radon decay products	ICRP 1981 [163051] Eckerman et al. 1988 [101069] 10 CFR Part 20 [104787]
Building shielding factor by radionuclide	NCRP 1999 [155894]

4.1.1 U.S. Census 2000

Technical information on population size, age distribution, industry of employment, and travel time of the residents of the Amargosa Valley census county division from the 2000 census conducted by the Bureau of the Census (2002 [159728]) were used in Sections 5.1 and 6.3.1 to determine the proportion of the population of the Amargosa Valley in four population groups. This information also was used to develop distributions of the time the population groups spend in five environments (Section 6.3.2), calculate gender-specific food consumption rates (Section 6.4.2), and determine the types of dwellings in the Amargosa Valley (Section 6.6). The 2000 census data are appropriate as they are based on the most recent and comprehensive census of the Amargosa Valley population. The data are specific to the people who reside in the Amargosa Valley, consistently with the requirements of 10 CFR 63.312(b) [156605] and discussed in Section 6.1. The data were collected and summarized in accordance with the requirements of the Bureau of the Census for census data. The data used in this analysis are presented in Tables 6.3-1, 6.3-2, 6.3-3, 6.3-5, 6.3-6, 6.3-7, and 6.3-9.

4.1.2 National Human Activity Pattern Survey

Estimates from the National Human Activity Pattern Survey (NHAPS) of time spent in various activities and locations are summarized in the *Analysis of the National Human Activity Pattern Survey (NHAPS) Respondents from a Standpoint of Exposure Assessment* (Klepeis et al. 1996 [159299]) and the *Exposure Factors Handbook* (EPA 1997 [116135]). This technical information was used to develop distributions of behavior times (Section 6.3.2). It is appropriate for this use because the NHAPS and associated data in the *Exposure Factors Handbook* (EPA 1997 [116135]) were collected by the U.S. Environmental Protection Agency (EPA), and because this is the largest and most complete compilation of activity patterns and time spent exposed to toxic pollutants by people in the U.S. (EPA 1997 [116135], p. 15-5; Klepeis 1999 [160094], pp. 368 to 371). For the 1992–1994 NHAPS survey, minute-by-minute, 24-hour diaries were kept by 9,386 people in the 48 contiguous U.S. states. The data were collected, summarized, and analyzed in accordance with rigorous, well defined methodologies, as described by Klepeis et al. (1996 [159299]). Applicability of data from this national survey to conditions in the Amargosa Valley are described in Section 6.3.2. The data used in this analysis are presented in Tables 6.3-8 and 6.3-10.

4.1.3 Parameters Related to Breathing Rate and the Respiratory Tract Model of ICRP Publication 66

Technical information related to the respiratory tract model of International Commission on Radiation Protection (ICRP) Publication 66 (ICRP 1994 [153705]), including the breathing rates and the nominal mix of exercise levels for various environments, was used to develop the values of breathing rate by population group and environment for the biosphere model (Section 6.3.3). The dosimetric model of the respiratory tract used in the biosphere model is that of ICRP Publication 30 (ICRP 1979 [110386], Section 5). This is consistent with the concept of total effective dose equivalent (Section 6.5.2). ICRP Publication 30 does not consider breathing rates for various levels of activity, but instead it uses the breathing rate of the reference man under conditions of light activity (ICRP 1979 [110386], Section 3.4). The ICRP Publication 66 data include the most recent recommended values of breathing rates for people involved in various levels of activity (sleeping, sitting, light exercise, heavy exercise). These activity-dependent breathing rates are used to calculate environment-dependent breathing rates for the biosphere model and are appropriate for intended use.

4.1.4 Food and Nutrient Intakes by Individuals in the United States

Technical information from the U.S. Department of Agriculture (USDA) 1994-96 Continuing Survey of Food Intakes by Individuals (USDA 2000 [154158]) was used in this analysis to develop consumption rate values for the receptor. This report is one in a series of nationwide dietary intake surveys conducted periodically by the USDA. These surveys are an important source of information on the food consumption patterns for various segments of the U.S. population. The survey data used in this analysis included the values of average daily intake of food by food categories, the fraction of population consuming the food in these categories, and the errors associated with these values for the western region of the country. One would expect that average consumption levels reported by the USDA and those found among the Amargosa Valley population may differ because of geographic differences in consumption preferences from one place to another, the time of the survey, and availability of different foodstuffs, among others. While direct consumption data for the Amargosa Valley are unavailable, the USDA data are the best available estimate of average daily consumption parameters and reflect nutritional needs and preferences of the surveyed individuals, which on average, are not expected to differ greatly between the populations. Regional differences are to some extent addressed by selecting the USDA data for the western U.S. The USDA consumption data are thus considered appropriate for use in this analysis. The values were used to develop the probability distribution functions for the consumption rates of locally produced food (Section 6.4.2).

4.1.5 1997 Regional Survey

Technical information collected during the 1997 regional survey (DOE 1997 [100332]) concerned consumption frequencies of locally produced food and demographic and selected lifestyle characteristics of the population in the Yucca Mountain region. Data on food consumption frequencies (DTN: MO0010SPANYE00.001 [154976]) were used to develop consumption rates for locally produced food (Section 6.4.2), and data related to evaporative cooler use (DTN: MO0106SPAECL02.016 [160256]) were used to develop a distribution of the proportion of homes with evaporative coolers (Section 6.3.4). These data are appropriate because they are from the most comprehensive and recent survey of the diet and living style of the people residing in the Amargosa Valley, consistently with the requirements of 10 CFR 63.312(b) [156605].

4.1.6 Meteorological Monitoring Data for Site 9 for the Period from 1993 to 1997

The information regarding temperature for the Amargosa Valley was obtained from the data for Meteorological Monitoring Site 9, which is the southern most Yucca Mountain Site station in the direction of Amargosa Valley. The data for the period from 1994 to 1997 are contained in 16 data sets listed in Table 4.1-1. The hourly temperature subset of these data was used to develop the evaporative cooler use factor for the Amargosa Valley in Section 6.3.4. The meteorological data for Meteorological Monitoring Site 9 are appropriate for use in this analysis because this site is located in northern Amargosa Valley at Gate 510 along the southern boundary of Nevada Test Site in the vicinity of Lathrop Wells. (CRWMS M&O 1999 [102877], p. 5).

4.1.7 Hourly United States Weather Observations 1990-1995

Hourly temperatures from the weather station at Spokane International Airport (Station ID 24157) were used to develop the evaporative cooler use factor for the glacial transition climate predicted to occur in the future at Yucca Mountain (Section 6.3.4). The data were obtained from the National Climatic Data Center (NCDC [n.d.] [161091]). These data are appropriate for this use because the future climate at Yucca Mountain during a glacial transition period is predicted to be equivalent to the current climate at Spokane Washington (USGS 2001 [158378], Table 2). The data were collected and summarized using the standardized methods of that agency.

4.1.8 Inadvertent Soil Ingestion Rate

The soil ingestion rate is calculated based on published studies and reviews of data on the rate of soil ingestion (Section 6.4.3). The primary sources of information used are the *Exposure Factors Handbook* (EPA 1997 [103038], Volume I, Chapter 4), a review article (Simon 1998 [160098]), and a study of soil ingestion in adults (Stanek et al. 1997 [160251]). The *Exposure Factors Handbook* summarizes data on human behaviors and characteristics that affect exposure to environmental contaminants and recommends values to use for those factors (EPA 1997 [103038], p. 1-1). The handbook summarizes relevant information and includes discussion and review of data applicability and related issues. The handbook is intended to serve as a support document to the EPA Guidelines for Exposure Assessment (as cited in EPA 1997 [103038], p. 1-1), which were developed to promote consistency among the various exposure assessment activities by providing a consistent set of exposure factors for calculating dose.

The article by Simon (1998 [160098]) was published as a special review paper in *Health Physics*. *Health Physics* is a peer-reviewed technical journal, which is an official publication of the Health Physics Society. The journal adheres to high standards for published articles, which are subject to review by experts in the field. Simon (1998 [160098]) gives a comprehensive review of the data on soil ingestion with the emphasis on risk assessments for soils contaminated with radionuclides.

Stanek et al. (1997 [160251]) summarize experimental results of soil ingestion by adults. Although studies of soil ingestion in children are relatively common, few researchers have studied adults. Stanek et al. (1997 [160251]) present the results of an experiment in which soil ingestion by adults was measured.

The sources are appropriate for the intended use because they contain values of soil ingestion rates that are representative of expected averages and include ranges of values and consideration of different environments (e.g., rural versus urban). This is important for the development of parameters for the biosphere model because it allows for developing more site-specific parameter values.

4.1.9 Dose Conversion Factors, Dose Coefficients, and Properties of Nuclides

Dose conversion factors (DCFs) and dose coefficients are expressions of specific dosimetric models and are used for converting radionuclide intake by inhalation and ingestion, as well as by exposure to sources external to the body, to radiation doses. The DCFs and dose coefficients developed in this report are based on technical information from EPA Federal Guidance Report (FGR) No. 11 (Eckerman et al. 1988 [101069]) and EPA FGR No. 12 (Eckerman and Ryman 1993 [107684]). Further discussion on the DCFs and dose coefficients can be found in Section 6.5.3 and 6.5.4. DCFs tabulated in FGR 11, and dose coefficients tabulated in FGR 12, allow calculating total effective dose equivalent, as defined in 10 CFR 63.2 [156605]. The use of DCFs and dose coefficients from these sources is appropriate because such an approach is consistent with the Nuclear Regulatory Commission (NRC) guidance on performance assessment methodology (NRC 2000 [157704], Sections 3.3.7.3.1 and 3.3.7.3.2).

DCFs for inhalation of radon decay products were developed based on ICRP (1981 [163051]) and Eckerman et al. (1988 [101069]). The values from ICRP Publication 32 (ICRP 1981 [163051]) are consistent with the ICRP Publication 30 dose methodology, and thus with the NRC guidance (NRC 2000 [157704], Section 3.3.7.1.2).

The data from FGR 12 (Eckerman and Ryman 1993 [107684]) and Lide and Frederikse (1997 [103178]) were used as a source of information on properties of radioactive nuclei, such as the radioactive decay half-lives and branching fractions.

4.1.10 Building Shielding Factors

Building shielding factors are taken from the National Council on Radiation Protection and Measurements (NCRP) Report No. 129 (NCRP 1999 [155894]). The NCRP reviewed the effect of shielding by dwellings of external exposure from soil contaminated with radionuclides that were reported in the literature. It then formulated recommendations of the shielding factor values in Report No. 129. This assessment, and the accompanying values of building shielding factors, are relevant for evaluating exposure to contaminated soil in the biosphere model because of the similarities in the type and geometry of the source of contamination.

4.1.11 Other Sources of Technical Information Used in this Analysis

Other sources of technical information used in this analysis included the rules at 10 CFR Part 63 [156605] and 10 CFR Part 20 [104787]. 10 CFR Part 63 [156605] was used as a source of information on the consumption rate of water by the RMEI. 10 CFR Part 20 [104787] was used to support development of dose conversion factor for radon decay products (Section 6.5.4). In addition, established fact information (Lide and Frederikse 1997 [103178]) was used as a source of information on half lives and branching fractions of some radionuclides (Table 6.5-1) and to develop distributions of exposure times (Section 6.3.2.2).

4.2 CRITERIA

Table 4.2-1 lists requirements from the *Project Requirements Document* (Canori and Leitner 2003 [161770], Table 2-3) that are applicable to this analysis. These requirements are for compliance with applicable portions of 10 CFR Part 63 [156605].

Table 4.2-1. Requirements Applicable to this Analysis

Requirement Number	Requirement Title	Related Regulation
PRD-002/T-015	Requirements for Performance Assessment	10 CFR 63.114
PRD-002/T-026	Required Characteristics of the Reference Biosphere	10 CFR 63.305
PRD-002/T-028	Required Characteristics of the Reasonably Maximally Exposed Individual	10 CFR 63.312

SOURCE: Canori and Leitner 2003 [161770], Table 2-3

Listed below are the acceptance criteria from the Biosphere Characteristics section of the *Yucca Mountain Review Plan, Draft Final Report* (NRC 2003 [162418], Section 2.2.1.3.14), based on meeting the requirements of 10 CFR 63.114, 10 CFR 63.305, and 10 CFR 63.312 [156605], that relate in whole or in part to this analysis. Similar acceptance criteria and descriptions from the Review Plan (NRC 2003 [162418], Sections 2.2.1.3.11; Airborne Transport of Radionuclides) also relate to portions of this analysis.

Acceptance Criterion 1 – System Description and Model Integration Are Adequate.

1. Total system performance assessment adequately incorporates important site features, physical phenomena, and couplings, and consistent and appropriate assumptions throughout the biosphere characteristics modeling abstraction process.

2. The total system performance assessment model abstraction identifies and describes aspects of the biosphere characteristics modeling that are important to repository performance, and includes the technical bases for these descriptions. For example, the reference biosphere should be consistent with the arid or semi-arid conditions in the vicinity of Yucca Mountain,

3. Assumptions are consistent between the biosphere characteristics modeling and other abstractions. For example, the U.S. Department of Energy should ensure that the modeling of FEPs such as climate change, soil types, sorption coefficients, volcanic ash properties, and the physical and chemical properties of radionuclides are consistent with assumptions in other TSPA abstractions.

Acceptance Criterion 2 – Data Are Sufficient for Model Justification.

1. The parameter values used in the license application are adequately justified (e.g., behaviors and characteristics of the residents of the Town of Amargosa Valley, Nevada, characteristics of the reference biosphere, etc.) and consistent with the definition of the reasonably maximally exposed individual in 10 CFR Part 63. Adequate descriptions of how the data were used, interpreted, and appropriately synthesized into the parameters are provided.

2. Data are sufficient to assess the degree to which features, events, and processes related to biosphere characteristics modeling have been characterized and incorporated in the abstraction. As specified in 10 CFR Part 63, the U.S. Department of Energy should demonstrate that features, events, and processes that describe the biosphere, are consistent with present knowledge of conditions in the region, surrounding Yucca Mountain. As appropriate, the sensitivity and uncertainty analyses (including consideration of alternative conceptual models) are adequate for determining additional data needs, and evaluating whether additional data would provide new information that could invalidate prior modeling results and affect the sensitivity of the performance of the system to the parameter value or model.

Acceptance Criterion 3 – Data Uncertainty Is Characterized and Propagated Through the Model Abstraction.

1. Models use parameter values, assumed ranges, probability distributions, and bounding assumptions that are technically defensible, reasonably account for uncertainties and variabilities, do not result in an under-representation of the risk estimate, and are consistent with the definition of the reasonably maximally exposed individual in 10 CFR Part 63.

2. The technical bases for the parameter values and ranges in the abstraction, such as consumption rates, plant and animal uptake factors, mass-loading factors, and BDCFs, are consistent with site characterization data, and are technically defensible.

3. Process-level models used to determine parameter values for the biosphere characteristics modeling are consistent with site characterization data, laboratory experiments, field measurements, and natural analog research.

4. Uncertainty is adequately represented in parameter development for conceptual models and process-level models considered in developing the biosphere characteristics modeling, either through sensitivity analyses, conservative limits, or bounding values supported by data, as necessary. Correlations between input values are appropriately established in the total system performance assessment, and the implementation of the abstraction does not inappropriately bias results to a significant degree.

4.3 CODES AND STANDARDS

No codes and standards, other than those identified the *Project Requirements Document* (Canori and Leitner 2003 [161770], Table 2-3) and determined to be applicable (Table 4.2-1), were used in this analysis.

5. ASSUMPTIONS

5.1 PROPORTION OF POPULATION

In Section 6.3.1, two assumptions are used to estimate the proportion of the adult population in the Amargosa Valley that could be classified into four population groups (population groups described in Section 6.2). These assumptions do not require confirmation because they are based on a careful interpretation of the Bureau of the Census methods and data, and because uncertainty associated with these assumptions is incorporated into the estimates of population proportions.

5.1.1 Commuters

For the groundwater exposure scenario, people who travel 10 minutes or more (one way) to work are classified as commuters and spend their working hours outside of the potentially contaminated area. For the volcanic ash exposure scenario, people who travel 35 minutes or more (one way) to work are classified as commuters.

This assumption is based on 10 CFR Part 63 [156605], which defines the location of the receptor and states that the RMEI should have a lifestyle representative of current Amargosa Valley residents (10 CFR 63.312 [156605]; see also Section 6.2); information from the Bureau of the Census (2002 [159728], Table P31) on the travel time to work by residents of the Amargosa Valley (Table 6.3-2); and the predicted depth of ash in northern Amargosa Valley after a volcanic eruption at Yucca Mountain.

Groundwater Exposure Scenario—For the groundwater exposure scenario, the receptor would not receive a dose from inhalation of, or exposure to, contaminated soil while commuting or working outside of areas where contaminated groundwater is used to irrigate crops or gardens. For this scenario, the amount of time it would take to drive out of the area contaminated by use of groundwater is determined based primarily on 10 CFR 63.312(c) [156605]. That requirement states that the RMEI is a hypothetical person who uses well water with average concentrations of radionuclides based on an annual water demand of 3,000 acre-feet. Based on an irrigation rate of 5 acre-feet per acre of crops (see justification below), use of 3,000 acre-feet would result in the contamination of 600 acres, or about one square mile (640 acres = 1 square mile). There are no conveyance systems (e.g., ditches, pipelines) in the Amargosa Valley to carry water long distances. Thus, 600 acres contaminated from pumping 3,000 acre-feet of water from one or a series of wells located on or near the center of the contaminated plume would be concentrated in a few square miles of land and a person in a vehicle could leave that area in less than 10 minutes. It is therefore assumed that people who commute 10 minutes or more, one way, work in areas that are not contaminated by groundwater.

Five acre-feet per irrigated acre is a reasonable approximation of the irrigation rate for the Amargosa Valley. During 1997, 10,454 acre-feet were used for irrigation in the groundwater basin that includes the Amargosa Valley (Thiel Engineering Consultants 1999 [147766], p. 15), and about 2,025 acres were planted in the portion of the Amargosa Valley where most farming occurs (CRWMS M&O 1997 [101090], Table 3-13). The resulting value of 5.2 acre-feet per acre of farmland may be a slight overestimate because the 1997 survey of agricultural lands did not include the entire groundwater basin and because some land may have been planted after the survey was conducted. The average amount of water withdrawn for irrigation throughout Nevada is 4.4 acre-feet per irrigated acre (State of Nevada 1999 [110928], p. 1-16).

This assumption is based on the amount of land irrigated by 3,000 acre-feet, rather than some higher acreage (e.g., the total amount of land irrigated in the Amargosa Valley) because calculations in the TSPA-LA of the concentration of radionuclides in groundwater must be based on the use of 3,000 acre-feet per year (10 CFR 63.312(c) [156605]). Basing this assumption on a larger area of agriculture would require an additional assumption that concentrations would be diluted in the larger amount of water needed to irrigate that area, which would be inconsistent with the TSPA-LA analysis. However, even if all agricultural land in the Amargosa Valley were considered, the driving time required to leave the area contaminated would be similar to that developed in this assumption because the Amargosa Valley is a small, isolated community. The farming region is a maximum of about 8 miles wide (along Farm Road); therefore, most residents can leave the irrigated area in less than 10 minutes of driving on the paved roads.

Volcanic Ash Exposure Scenario—For this scenario, the receptor could receive a radiation dose from ash deposited on the ground surface in residential and work environments and from ash redistributed into those environments from aeolian and fluvial processes (calculation of dose during the volcanic eruption is addressed outside of the biosphere model and therefore is not discussed here). Therefore, the amount of time required to travel out of the contaminated area is based on information about the distribution of ash following a volcanic eruption at Yucca Mountain.

The amount of ash initially deposited at a location would depend primarily on characteristics of the volcano, wind direction, and distance from Yucca Mountain. High-altitude winds in the vicinity of Yucca Mountain usually blow to the north or northeast; much less often to the southwest, south, or southeast; and rarely to the east, west, or northwest (BSC 2001 [157876], pp. 41, 42, and I-7). Under normal, variable wind conditions, predicted ash depths 20 km south of Yucca Mountain, calculated for the *Total System Performance Assessment for the Site Recommendation* (CRWMS M&O 2000 [153246], Section 3.10.5.1 and Figure 3.10-14), ranged from less than 1×10^{-8} cm to about 10 cm. About 66 percent of predicted depths were less than 0.1 mm, about 80 percent were less than 1 mm, and about 95 percent were less than 10 mm. However, the location for which ash depth was calculated in that report may differ from that required by 10 CFR 63.312(a) [156605]. Ash depth has not been predicted for other locations. The information regarding the consequences of contaminated tephra release is currently being revised; when it becomes available, the impact on this analysis will be evaluated. However, it is not anticipated that the conclusions of this analysis will be affected because they do not depend on the numerical results of the volcanic consequence modeling.

Based on this information, it is likely that at least a thin layer of ash would be deposited throughout most or all of the Amargosa Valley and at many work areas on the Nevada Test Site. It is much less likely that ash would be deposited at more distant population and employment centers to the south (Pahrump), east (Las Vegas), and west (Beatty).

Over time, some ash initially deposited at or near Yucca Mountain would be washed into the Amargosa Valley via Fortymile Wash. Ash may also be redistributed into the upper reaches of the Amargosa River near Beatty, Nevada, via Beatty Wash and other drainages that flow west from Yucca Mountain. Because they are outside of the watersheds where substantial amounts of ash would be deposited initially, large amounts of ash probably would not be redistributed into Las Vegas and Pahrump.

For the volcanic ash exposure scenario, it is assumed that, on average, people who commute to work less than 35 minutes (one way) remain in the contaminated area. Within 35 minutes, a person living in northern Amargosa Valley could travel to work sites in the Amargosa Valley, Beatty, and much of the Nevada Test Site. They probably could not travel to Pahrump or to other employment centers in Clark County (e.g., Indian Springs, Las Vegas) in only 35 minutes.

The minimum value of the distribution of the proportion of the population classified as commuters is calculated as the average minus two standard errors (SE) (in contrast to ± one SE for other population groups) to account for uncertainty in the distribution of ash and the travel time required to leave contaminated areas (Section 6.3.1).

5.1.2 Local Outdoor Workers

For both exposure scenarios, all residents working in agriculture, 25% of those working in construction, 10% of those working in the utilities industry, and 10% of miners are classified as local outdoor workers who spend their working hours outdoors in the potentially contaminated area. To account for uncertainty in the distribution of ash, the upper bound of the distribution of local outdoor workers is calculated as two times the SE of the mean. All other distribution tails for both scenarios are calculated as one time the SE of the mean.

This assumption is based on information from the Bureau of the Census (2002 [159728], Table P49) on the number of people working in various industries (Table 6.3-3). The population group "local outdoor workers" includes people who work outdoors and disturb (and therefore resuspend) contaminated soil. Because motor vehicle operators and others working in the transportation industry spend most of their time in enclosed cabs, they would not be exposed to substantial amounts of contaminated soil, and they are not considered local outdoor workers.

It is assumed that all residents of the Amargosa Valley who work in agriculture, forestry, or fisheries work outdoors in that valley.

Many people in the construction and utilities industries also work outdoors, but it is likely that only a few of these people work in the Amargosa Valley and conduct soil-disturbing activities. To account for these local workers, it is assumed that 25% of construction workers and 10% of utility workers spend their work time outdoors in the Amargosa Valley. Because of the small number of workers in these industries, estimates of exposure times are insensitive to these percentages.

One-hundred and nineteen people in Amargosa Valley are employed in the mining industry (Table 6.3-3). Of these, about half (58; Bureau of the Census 2002 [159728], Table P50) list their occupation as extraction workers (i.e., miners). Many of these miners probably work in hard-rock or clay mines around Beatty (Nevada Department of Minerals et al. 1991 [160176], Section VI; Driesner and Coyner 2001 [160175], Section VI]). In 1990, when gold and silver prices were relatively high (Driesner and Coyner 2001 [160175], p. 23), six of eight operational mines in southern Nye County were located around Beatty. The mines employed over 400 people, with about 75% working at the Bullfrog Mine. The only mines in or near the Amargosa Valley in 1990 were a clay mine near the California border, employing 54 people, and a cinder mine at the Lathrop Wells Cone (at the north end of the Amargosa Valley), employing two people (Nevada Department of Minerals et al. 1991 [160176], Section VI). Because the Bullfrog Mine closed during the 1990s due to exhaustion of profitable ores and lower gold prices (Driesner and Coyner 2001 [160175], p. 23), few mines were operating in the region in 2000. According to Driesner and Coyner (2001 [160175], Section VI), there were two operating mines near Beatty in 2000 (employing about 50 people) and a clay mine in southern Amargosa Valley (employing 33 people). Davis (2001 [160096], p. 59) also lists the cinder mine at the Lathrop Wells Cone as operational and employing seven people in 2000.

The only miners likely to work in or near an area potentially contaminated by water from a well or a substantial amount of volcanic ash are those working at the cinder mine or at temporary sand and gravel operations that could be developed in the northern part of the valley. The specialty clays mined in the Amargosa Valley are only found in the lacustrine sediments at the southern end of the valley (Castor 2001 [160095], pp. 40 and 42). Even if ash were to fall at those clay mines or at hard-rock mines in the region, miners there likely would only be exposed for a very short time because the ash would have to be removed before subsurface clay or rock could be mined. Estimates of activity budgets are relatively sensitive to the percentage of miners included by this assumption because miners are a substantial portion of the work force. To ensure that the number of miners working in the potentially contaminated area is not underestimated, it is assumed that 10% of the Amargosa Valley residents employed in the mining industry work outdoors in contaminated areas.

This assumption is intended for use in the groundwater and volcanic ash exposure scenarios. However, there is a small possibility that contaminated ash would be deposited at some mines and other outdoor work locations in southern Amargosa Valley, Beatty, and elsewhere. To account for uncertainty in the distribution of ash and the subsequent exposure to additional miners and other outdoor workers following a volcanic eruption, the upper bound of the distribution of local outdoor workers is calculated as two times the SE of the mean, as described in Section 6.3.1.

There are no upstream assumptions in the references cited in this section.

5.2 ABSENCE OF GEOPHAGIA

Calculations of soil ingestion rate for the RMEI was based on the assumption that 100% of the soil intake was inadvertent, i.e., that there is no geophagia among adults residing in the Amargosa Valley. Geophagia is a disorder characterized by purposeful eating of soil. People that exhibit geophagia have a greater soil intake than those for which all soil intake is inadvertent. This disorder is uncommon (EPA 1997 [103038], p. 4-1). To comply with 10 CFR

63.312(b), which states that projections of diet must be based on the average of the people in the Amargosa Valley, geophagia is not considered in the estimate of soil ingestion in Section 6.4.3.

6. ANALYSIS

The objective of this analysis is to develop values for the parameters used in the ERMYN that represent characteristics of the human receptor. The receptor considered in this analysis, the RMEI, is defined in Section 6.1. The methods and parameters used in the biosphere model to evaluate receptor exposure are presented in Section 6.2.

Characteristics of the RMEI are based on regulations (10 CFR Part 63 [156605]; see also Section 6.1) and on the range of conditions typical of the environment and population in the Amargosa Valley. Local lifestyle and diet characteristics are considered. Lifestyle parameters are discussed in Section 6.3 and Section 6.6, and include the type and location of employment as well as the associated proportions of population, land use, activity budgets (i.e., amount of time spent conducting activities and the location where those activities occur), recreation, and characteristics of dwellings. Lifestyle characteristics are considered in the biosphere model in parameters for the exposure time, fraction of houses with evaporative coolers, evaporative cooler use factor; inadvertent soil ingestion rate, and building shielding factor.

Dietary parameters are discussed in Section 6.4. Dietary characteristics include consumption rate of contaminated food and water. These characteristics are considered in the model parameters for consumption rate of water and consumption rates of locally produced leafy vegetables, other vegetables, fruit, grain, meat, poultry, milk, eggs, and fish.

This analysis report also develops values for breathing rates (which are related to physiology of the receptor; Section 6.3.3), describes the dosimetric methods used to convert internal and external exposure of the receptor to radiation doses, selects dose coefficients for internal and external exposure (Section 6.5), and building shielding factors (Section 6.6).

6.1 DEFINITION OF THE RECEPTOR

In 2001, the EPA promulgated *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada* (40 CFR 197 [155238]). The EPA rule includes an Individual-Protection Standard (40 CFR 197.20 and 197.21 [155238]) for the performance of the repository, expressed as the annual dose limit to the RMEI. The NRC incorporated these standards into licensing regulations in *Disposal of High-level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada* (10 CFR Part 63 [156605]), consistent with requirements of the Energy Policy Act of 1992.

Postclosure performance objectives include the requirement that radiological exposure to the RMEI are within the specified limits (10 CFR 63.113 [156605]). The limits for the individual protection standard, as in the EPA rule, are expressed in terms of an annual dose that includes all potential pathways of radionuclide transport and exposure (10 CFR 63.311 [156605]).

The RMEI is a hypothetical receptor who meets the following criteria (10 CFR 63.312 [156605]):

- Lives above the highest concentration of radionuclides in the plume of contamination.

- Has a diet and lifestyle representative of people who now reside in the Amargosa Valley based on surveys of the people residing in the Amargosa Valley that determine current diets and lifestyles, and then use the mean values of these factors in the assessments conducted for 10 CFR 63.311 and 10 CFR 63.321 [156605].

- Uses well water with average concentrations of radionuclides based on an annual water demand of 3,000 acre-feet.

- Drinks 2 liters of water per day from wells drilled into the groundwater from a point above the highest concentration of radionuclides in the plume of contamination.

- Is an adult who is metabolically and physiologically consistent with present knowledge of adults.

The required characteristics of the RMEI include living in the accessible environment above the highest concentration of radionuclides in the plume of contamination (10 CFR 63.312(a) [156605]). The location within the accessible environment with the highest concentrations likely would be above the contaminated groundwater plume at or near the southern edge of the controlled area (i.e., as close to Yucca Mountain as is accessible). The southern edge of the controlled area can extend no farther south than 36^{o}40'13.6661" North latitude (10 CFR 63.302, definition of Controlled Area (1)(i) [156605]), which is north of Highway 95 near the southern boundary of the Nevada Test Site. The approximate location of the contaminated plume has been predicted to be below Fortymile Wash (DOE 2001 [153849], Figure 4-147). The exact location of the RMEI within this general area is not important for the parameters considered in this analysis because the parameter values are independent of the exact location.

Regulation 10 CFR 63.312(b) ([156605]) refers to the “Town of Amargosa Valley”; however, there is no legally defined location associated with that name. The most applicable legally defined region is the Nye County unincorporated township or taxing district of Amargosa Valley (Figure 6.1-1). Throughout this report, the terms “residents of the Amargosa Valley”, “people living in the Amargosa Valley”, “Amargosa Valley population”, and similar terms refer to Amargosa Valley residents living south of Yucca Mountain (unless otherwise specified). This region includes the Amargosa Valley taxing district.

To meet the requirement in 10 CFR 63.312(b) [156605]), requiring the use of mean values for factors related to dietary and lifestyle characteristics, all parameter distributions developed in this report are based on mean values for the population under consideration, and variation is calculated based on the SE of the mean. Thus, the RMEI is a hypothetical composite individual with dietary and lifestyle characteristics represented by mean values of the Amargosa Valley population.

To address other requirements of 10 CFR 63.312(b) [156605], information from two surveys of the people living in Amargosa Valley were used in this analysis to determine average values of current diets and living styles. To develop specific parameter values required by the biosphere model, information from these surveys was combined with national information on behavior patterns, as described below.

A regional survey was conducted in 1997 to determine the frequency at which people in the Amargosa Valley consume locally produced food and to quantify other lifestyle characteristics (e.g., use of evaporative coolers) (DOE 1997 [100332]). Only data from people who listed Amargosa Valley as their place of residence were included in this analysis. Information from this survey was combined with information on average daily intakes from the USDA 1994-96 Continuing Survey of Food Intakes by Individuals (USDA 2000 [154158]) to calculate average consumption rates for locally produced food. Uncertainty associated with using this national information on food consumption rates is discussed in Section 6.4.2

Survey data from the 2000 census (Bureau of the Census 2002 [159728]) were used to determine the proportion of the Amargosa Valley population in four population groups (Section 6.3.1) and to estimate the average amount of time the receptor spends in five environments (Section 6.3.2). Data from the Amargosa Valley census county division were used in this analysis. This area (Figure 6.1-1, Tract 980300 BG3) includes all residents of the Amargosa Valley taxing district except some people living near Crystal. Data from Crystal were not used because information about people living there was included in a census county division with many residents from Pahrump (Figure 6.1-1). Because the Amargosa Valley census county division includes residents of the Amargosa Valley living in areas most likely to be affected by the Yucca Mountain repository, the data are a valid representation of the lifestyle characteristics of "the people who now reside in the town of Amargosa Valley, Nevada." Information on lifestyle characteristics from the 2000 census were used with data from the EPA NHAPS (Klepeis et al. 1996 [159299]; EPA 1997 [116135]) on time spent in various environments to determine average values for activity budgets. Uncertainty associated with the use of national data on activity patterns to determine the lifestyle characteristics of the people of the Amargosa Valley is discussed in Section 6.3.2.

The RMEI is defined as an adult (10 CFR 63.312(e) [156605]). For dose assessments, an adult is usually defined as an individual 18 or more years old (10 CFR 20.1003 [104787]). Information on people 18 or more years old was used throughout this analysis with the following two exceptions. The Bureau of Census (2002 [159728]) reports some data used in this analysis (e.g., number of hours worked per year; Tables 6.3-1 and 6.3-5) for residents 16 or more years old. Because there is no way to separate census information about 16 and 17 year olds from information on older residents, some analyses in Section 6.3.1 and 6.3.2 were derived from residents 16 or more years old. This has little influence on the results of this analysis because only an estimated 3.7% (32 of 862; Table 6.3-9) of Amargosa Valley residents 16 or more years old were 16 or 17 years old. Average daily intake and frequency of consumption used in Section 6.4.2 (USDA 2000 [154158] to calculate consumption rates of locally produced foods were based on national survey results for males and females 20 or more years old. This was done because survey information for persons 18 and 19 years old could not be separated from younger age groups. This has little influence on the results of this analysis because 18 and 19 year olds only comprised 4.7 percent (39 of 830; Table 6.3-9) of the Amargosa Valley residents 18 or older in 2000.

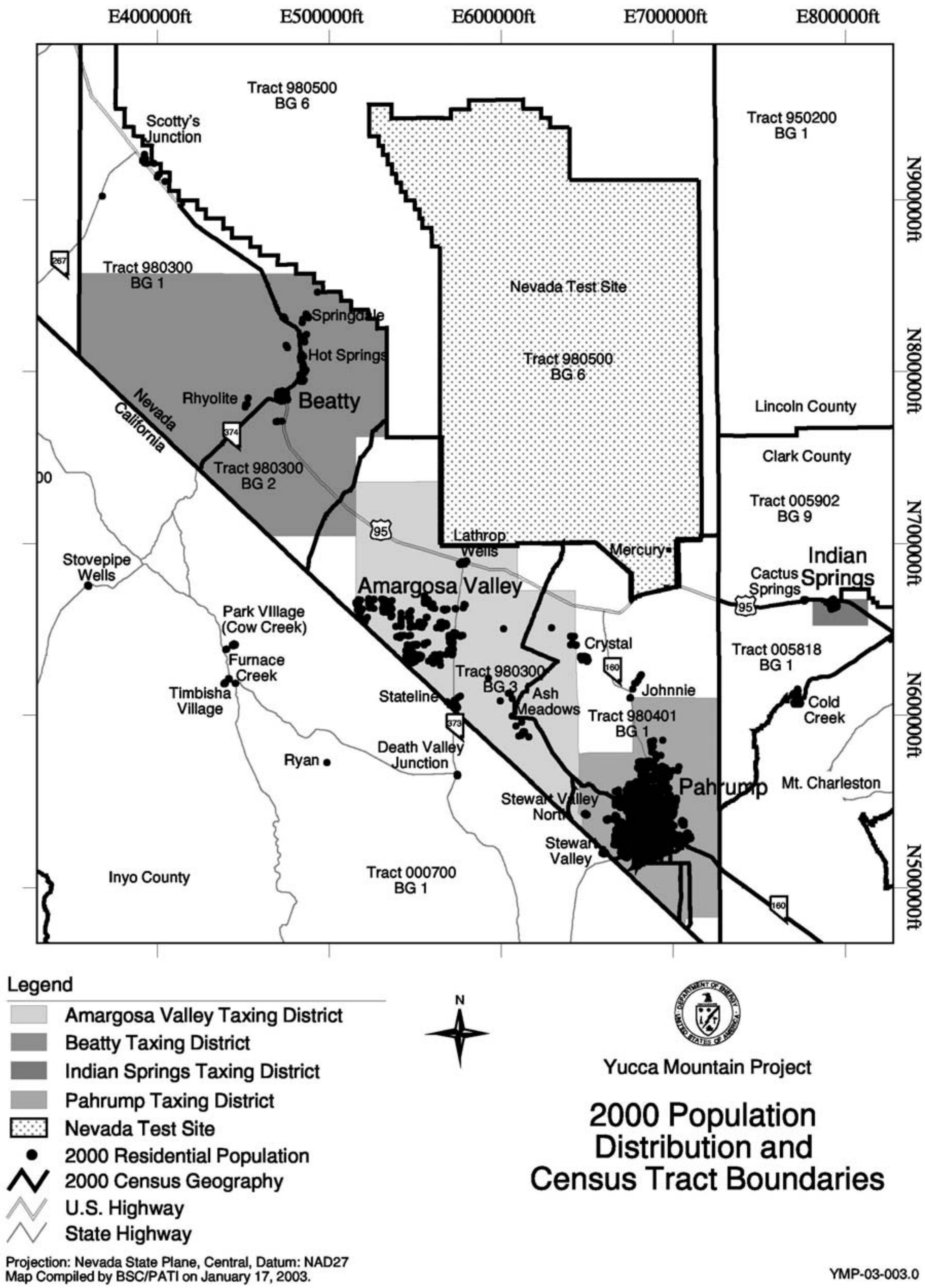


Figure 6.1-1. Southcentral Nevada Census Geography

The characteristics of the RMEI and the individual protection standard of 0.15 mSv/year (15 mrem/year) (10 CFR 63.311 [156605]) are considered protective of the general population. The general population includes individuals who are represented by the RMEI and all other individuals residing in the Yucca Mountain area. Because the community represented by the RMEI will have a higher estimated dose than the highest exposed individual who does not live in that community, an individual dose limit for the RMEI is protective of all individuals (66 FR 55732 [156671], p. 55750). Because the location of the RMEI is directly above the path of the contamination plume and because the diet and lifestyle are representative of people living in the Amargosa Valley, the dose to the RMEI bounds any doses received by other individuals in the population.

6.2 METHODS FOR EVALUATING RECEPTOR RADIATION EXPOSURE, INTAKES, AND DOSES

A person living in a contaminated environment can become exposed to radiation via many exposure pathways. The exposure pathways originate in the contaminated environmental medium, such as soil, air, or water. Contact with these media results in external exposure or intake of radionuclides by inhalation or ingestion. Exposure pathways included in the biosphere model, and the associated parameters related to characteristics of the receptor, are shown in Table 6.2-1. The exposure pathways for the volcanic ash exposure scenario are the same as those for the groundwater exposure scenario, except for the omission of pathways directly associated with contaminated water (e.g., water intake, consumption of freshwater fish, inhalation of aerosols generated by evaporative coolers) or associated with radionuclides that are not considered for volcanic releases (^{14}C).

Methods for calculating annual doses to the RMEI from the three major radiation exposure pathways (external exposure, inhalation, and ingestion) are described in this section. To estimate radiation doses, the biosphere model calculates radionuclide concentrations in the environmental media. Then the external exposure or radionuclide intake is evaluated considering the dietary and lifestyle characteristics of the receptor. The conversion of radionuclide intake or external exposure to dose is accomplished using DCFs or dose coefficients.

Within the biosphere model, BDCFs (which differ from DCFs, as defined in Section 6.6), rather than total doses, are calculated. BDCFs are numerically equal to the dose per unit concentration of a radionuclide in a source media (e.g., groundwater or ash). These conversion factors are then used in the TSPA (where the concentrations of radionuclides in the source media are estimated) to calculate total dose. Therefore, in this report, descriptions and references to dose calculations in the biosphere model infer that the calculation uses a unit concentration of radionuclides in a medium.

Table 6.2-1. Biosphere Model Exposure Pathways and Associated Parameters Related to Receptor Characteristics

Environmental Medium	Exposure Mode	Exposure Pathways[a]	Associated Parameters Related to the Receptor Characteristics
WATER	Ingestion	Water intake *	▪ Annual consumption rate of water
SOIL	Ingestion	Inadvertent soil ingestion	▪ Annual inadvertent soil ingestion rate ▪ DCFs for ingestion by radionuclide
	External	External radiation exposure	▪ Proportion of population per population group ▪ Annual exposure time per population group and environment ▪ Building shielding factor per radionuclide ▪ Dose coefficient for exposure to contaminated ground surface per radionuclide ▪ Dose coefficient for exposure to soil contaminated to an infinite depth by radionuclide
AIR	Inhalation	Breathing of airborne particulates Breathing of gases (^{222}Rn and decay products) Breathing of gases (^{14}C)* Breathing of aerosols from evaporative coolers*	▪ Proportion of population per population group ▪ Annual exposure time per population group and environment ▪ Breathing rate per environment and population group ▪ Fraction of houses with evaporative coolers ▪ Evaporative cooler use factor ▪ DCFs for inhalation by radionuclide ▪ DCF for inhalation of radon decay products
PLANTS	Ingestion	Consumption of locally produced crops: ▪ Leafy vegetables ▪ Other vegetables ▪ Fruit ▪ Grain	▪ Annual consumption rate of locally produced crops ▪ DCFs for ingestion by radionuclide
ANIMALS	Ingestion	Consumption of locally produced animal products: ▪ Meat ▪ Poultry ▪ Milk ▪ Eggs	▪ Annual consumption rate of locally produced animal products ▪ DCFs for ingestion per radionuclide
AQUATIC ORGANISMS	Ingestion	Consumption of locally produced freshwater fish*	▪ Annual consumption rate of locally produced fish ▪ DCFs for ingestion per radionuclide

SOURCE: Based on descriptions of exposure pathways in the *Biosphere Model Report* (BSC 2003 [160699], Section 6.3)

NOTES:

[a] All pathways are the same for the groundwater and volcanic ash exposure scenarios except those marked with an asterisk, which are not included in the volcanic ash exposure scenario.

To account for variation and uncertainty in the characteristics of the RMEI and concentrations of radionuclides in the biosphere, the ERMYN uses a micro-environmental modeling approach to calculate inhalation and external exposure doses. For micro-environmental models, the total exposure environment (i.e., the biosphere) is divided into segments, or environments, with different concentrations of contaminants. The contaminant concentration, time spent exposed to the contaminant, and intake rate or exposure factor (e.g., breathing rate, shielding factor) are determined for each environment, and the total dose is calculated as the sum of the dose within all environments (Mage 1985 [162465], pp. 409 to 410). Micro-environmental models are commonly used to evaluate exposure to particulate matter and other contaminants (Duan 1982 [162466]; Mage 1985 [162465]; Klepeis 1999 [160094]).

In the ERMYN model, the biosphere is divided into five environments. These mutually exclusive environments represent the behavioral and environmental combinations for which people may receive substantially different rates of exposure via inhalation or external exposure.

Away from Potentially Contaminated Area–This category includes time spent away from areas contaminated by groundwater or volcanic ash, including time spent working and commuting to work by people who work outside the contaminated areas.

Active Outdoors–Time spent active outdoors includes time spent outdoors in contaminated areas conducting activities that resuspend soil. This includes conducting dust-generating activities while working (e.g., plowing, excavating, and livestock operations) and recreating (e.g., gardening, landscaping, and riding horses or motorbikes) outdoors. Because dust concentrations decrease rapidly after dust-disturbing activities cease (e.g., Pinnick et al. 1985 [159577], pp. 103 to 104), this category is limited to the time when the activities are occurring.

Inactive Outdoors–This category represents the time spent commuting within contaminated areas and time spent outdoors in the contaminated area conducting activities that do not resuspend soil (e.g., sitting, swimming, walking, barbecuing, and equipment maintenance). Commuting time is included in this category because major roads in the Amargosa Valley are paved, and commuting on those roads would not resuspend much soil.

Asleep Indoors–This category includes time spent sleeping indoors within contaminated areas.

Active Indoors–This category includes time spent awake, indoors within contaminated areas, including work time. In the model, this is calculated as the remainder of the day not spent in the other four environments.

To account for variation and uncertainty in the amount of time the receptor spends in these environments, the model considers four mutually exclusive population groups (Section 6.3.1). The exposure times per environment for the RMEI are calculated as the weighted average of the exposure times per environment for all population groups (e.g., Equation 6.2-3). These groups represent the range of behaviors that most influence the amount of time people would be exposed to radionuclides via inhalation of resuspended soil, use of evaporative coolers, and external exposure. Variation among individuals in these exposure pathways is influenced primarily by the amount of time they spend indoors and outdoors within contaminated areas, and the amount of time they spend away from contaminated areas. For adults, variation among these time factors primarily is a function of occupational characteristics, as people working out of a contaminated area generally would experience less exposure than people that remain within the area, and people who work outdoors would be exposed at a different level than those who remain indoors. Therefore, the categories are based on work location and type of occupation. Estimates of the proportion of the adult population of the Amargosa Valley in each group are given in Section 6.3.1.

Non-workers–Residents who are unemployed or not in the labor force, including retired persons.

Commuters–Residents who work in uncontaminated areas.

Local Outdoor Workers–Residents who work outdoors, disturb, and resuspend contaminated soil.

Local Indoor Workers–Residents who work indoors (or outdoors in enclosed vehicles) in contaminated areas. The proportion of the population in this group is calculated as the proportion not in the other groups.

6.2.1 Evaluation of External Exposure

Doses received from external sources of radiation originate from radionuclides in the soil, air, and water. For external exposure, radiation emitters are external to the human body, and therefore the exposure continues only as long as a person is in the immediate vicinity of, or in direct contact with, the contaminated medium, such as soil, air, or water. The doses from external exposure can be evaluated using radionuclide media concentrations and the duration of exposure to these media in combination with dose coefficients for external exposure to photons and electrons emitted by radionuclides distributed in the contaminated media.

The annual individual dose to a receptor from external exposure to primary radionuclide *i* in contaminated soil may include contributions from other primary radionuclides formed in the soil as a result of radioactive decay of radionuclide *i*. The combined dose is estimated using the following expression (BSC 2003 [160699], Section 6.4.7.1):

$$D_{ext,i} = \sum_{l} D_{ext,l} = \sum_{l} EDCF_{soil,l} \frac{Cs_l}{d} \left[\sum_{n} f_{ext,l,n} \left(\sum_{m} PP_m (3600 \times t_{n,m}) \right) \right] \qquad \text{Eq. 6.2-1}$$

where

$D_{ext,\,i}$	=	annual dose from external exposure to primary radionuclide *i* in soil (Sv/yr)
$D_{ext,\,l}$	=	dose from external exposure to radionuclide *l* in a decay chain of a primary radionuclide *i* (Sv/yr)
L	=	index of radionuclide in a decay chain; *l* = 0 for primary radionuclide
$EDCF_{soil,\,l}$	=	effective dose coefficient for exposure to soil contaminated to an infinite depth for a radionuclide *l* in a decay chain of a primary radionuclide *i* (Sv/s per Bq/m^3)
Cs_l	=	saturation activity concentration in surface soil for a radionuclide *l* in a

		decay chain of a primary radionuclide i (Bq/m^2)
D	=	depth of surface soil (m)
$f_{ext,\,l,\,n}$	=	building shielding factor for external exposure to radionuclide l in soil in environment n (dimensionless)
n	=	environment index; n = 1 for active outdoors, 2 for inactive outdoors, 3 for active indoors, 4 for asleep indoors, and 5 for away from the contaminated area
m	=	population group index; m = 1 for commuters, 2 for local outdoor workers, 3 for local indoor workers, and 4 for non-workers
PP_m	=	fraction of total population in population group m
$t_{n,\,m}$	=	number of hours per year a population group m spends in the environment n (hr/yr)
3600	=	unit conversion factor, 3600 s/hr.

This analysis develops values for the dose coefficients for individual radionuclides that are used to develop the effective dose coefficients for exposure to contaminated soil, $EDCF_{soil,l}$ (Section 6.5); the building shielding factor for external exposure to radionuclides in soil, $f_{ext,\,l,\,k}$ (Section 6.6); the amount of time population groups spend in defined environments, $t_{n,\,m}$ (Section 6.3); and the fraction of total population in specified population groups, PP_m (Section 6.3).

6.2.2 Evaluation of Inhalation Exposure

External exposure, described in the previous section, results from emissions that arise outside the human body. This is in contrast to the intake of radionuclides by inhalation or ingestion, for which radiation is emitted inside the body and the exposure continues following the intake for as long as the radionuclides remain in the body. The inhalation dose is caused by inhalation of contaminated air. Three mechanisms of air contamination were included in the biosphere model: resuspension of contaminated soil, the use of evaporative coolers, and gaseous emission from soil (which includes exhalation of ^{222}Rn, and ^{14}C from soil). The total inhalation dose is the sum of inhalation doses resulting from these processes (BSC 2003 [160699], Section 6.4.8) such that

$$D_{inh,i} = D_{inh,p,i} + D_{inh,e,i} + D_{inh,g,i} \qquad \text{Eq. 6.2-2}$$

where

$D_{inh,\,i}$	=	annual dose from inhalation exposure to radionuclide i (Sv/yr)
$D_{inh,\,p,\,i}$	=	annual dose from inhalation exposure to radionuclide i in resuspended particles (Sv/yr)
$D_{inh,\,e,\,i}$	=	annual dose from inhalation exposure to radionuclide i in air resulting from operation of evaporative cooler (Sv/yr)
$D_{inh,\,g,\,i}$	=	annual dose from inhalation exposure to radionuclides in air resulting from gaseous emission of radionuclide i from soil (Sv/yr).

The last dose component (Equation 6.2-2) applies only to the inhalation of ^{222}Rn decay products, and ^{14}C.

6.2.2.1 Inhalation of Airborne Particulates

The annual dose to a receptor from inhalation exposure to primary radionuclide i in resuspended particles includes all primary radionuclides (l) in the decay chain of radionuclide i. The combined dose is estimated (BSC 2003 [160699], Section 6.4.8.1) as

$$D_{inh,\,p,i} = \sum_{l} D_{inh,\,p,l} = \sum_{l} EDCF_{inh,l}\left[\sum_{n} Ca_{h,l,n}\; F_n\; BR_n \sum_{m}\left(PP_m\; t_{n,m}\right)\right] \qquad \text{Eq. 6.2-3}$$

where

$D_{inh,\,p,\,i}$	=	annual dose from inhalation exposure to primary radionuclide i in resuspended particles (Sv/yr)
$D_{inh,\,p,\,l}$	=	annual dose from inhalation exposure to radionuclide l in a decay chain of primary radionuclide i in resuspended particles (Sv/yr)
L	=	radionuclide index for a decay chain, $l = 0$ for primary radionuclide, 1 for the 1st decay product, 2 for the 2nd decay product
$EDCF_{inh,\,l}$	=	effective DCF for inhalation of radionuclide l in a decay chain of primary radionuclide i (Sv/Bq)
N	=	environment index; $n = 1$ for active outdoors, 2 for inactive outdoors, 3 for active indoors, 4 for asleep indoors, and 5 for away from the contaminated area
$Ca_{h,\,l,\,n}$	=	activity concentration of radionuclide l in a decay chain of primary radionuclide i in air for environment n (Bq/m^3)
F_n	=	correction factor corresponding to the evaporative cooler use in environment n (dimensionless) ($F_n = 1$ if evaporative coolers are not associated with a given environment)
BR_n	=	breathing rate for environment n (m^3/hr)
M	=	population group index; $m = 1$ for commuters, 2 for local outdoor workers, 3 for local indoor workers, and 4 for non-workers
PP_m	=	fraction of total population in population group m
$t_{n,\,m}$	=	annual number of hours a population group m spends in environment n (hr/yr).

This analysis develops values for the inhalation DCFs for individual radionuclides that are used to develop the effective DCFs for inhalation, $EDCF_{inh,\,l}$ (Section 6.5); the environment-dependent breathing rate, BR_n (Section 6.3); the amount of time population groups spend in defined environments, $t_{n,\,m}$ (Section 6.3); and the fraction of total population in specified population groups, PP_m (Section 6.3).

6.2.2.2 Inhalation of Aerosols Produced by Evaporative Coolers

The inhalation dose attributable to the operation of evaporative coolers is estimated (BSC 2003 [160699], Section 6.4.8.2) as

$$D_{inh,\,e,\,i} = EDCF_{inh,\,i}\; Ca_{e,\,i}\; f_{cooler}\; f_{use} \sum_{n=3}^{4} BR_n \left(\sum_m PP_m\; t_{n,\,m} \right) \qquad \text{Eq. 6.2-4}$$

where

$D_{inh,\,e,\,i}$	=	annual dose from inhalation of primary radionuclide *i* from evaporative cooler operation (Sv/yr)
$EDCF_{inh,\,i}$	=	effective DCF for inhalation of radionuclide *i* (Sv/Bq)
$Ca_{e,\,i}$	=	activity concentration of radionuclide *i* in indoor air attributable to the evaporative cooler operation (Bq/m^3)
f_{cooler}	=	fraction of houses with evaporative coolers (dimensionless)
f_{use}	=	annual evaporative cooler use factor (dimensionless).

This analysis develops values for the inhalation DCFs for individual radionuclides that are used to develop the effective DCFs for inhalation, $EDCF_{inh,\,l}$ (Section 6.5); the environment-dependent breathing rate, BR_n (Section 6.3); the amount of time population groups spend in defined environments, $t_{n,\,m}$ (Section 6.3); the fraction of total population in specified population groups, PP_m (Section 6.3), the fraction of houses with evaporative coolers, f_{cooler}, (Section 6.3); and the annual evaporative cooler use factor, f_{use}, (Section 6.3).

6.2.2.3 Inhalation of Carbon-14

The inhalation dose from ^{14}C is calculated using a method similar to that used for assessment of inhalation dose from resuspended particulates (BSC 2003 [160699], Section 6.4.8.3), which is

$$\begin{aligned} D_{inh,g,C-14} &= \sum_n D_{inh,g,C-14,n} \\ &= DCF_{inh,C-14}\; Ca_{g,C-14} \sum_n BR_n \left(\sum_m PP_m\; t_{n,m} \right) \end{aligned} \qquad \text{Eq. 6.2-5}$$

where

$D_{inh,\,g,\,C\text{-}14}$	=	annual dose from inhalation of ^{14}C in gaseous form (Sv/yr)
$D_{inh,\,g,\,C\text{-}14\,n}$	=	annual dose from inhalation of gaseous ^{14}C for environment *n* (Sv/yr)
$Ca_{g,\,C\text{-}14}$	=	activity concentration of ^{14}C in air (Bq/m^3)
$DCF_{inh,\,C\text{-}14}$	=	DCF for inhalation of ^{14}C (Sv/Bq).

This analysis develops values for the inhalation DCFs for ^{14}C, $DCF_{inh,\,C\text{-}14}$ (Section 6.5); the environment-dependent breathing rate, BR_n (Section 6.3); the amount of time population groups spend in defined environments, $t_{n,m}$ (Section 6.3); and the fraction of total population in specified population groups, PP_m (Section 6.3).

6.2.2.4 Inhalation of Radon Decay Products

The dose due to inhalation of radon decay products is evaluated in the biosphere model (BSC 2003 [160699], Section 6.4.8.4) as

$$D_{inh,g,Rn-222} = \sum_n D_{inh,g,Rn-222,n}$$

$$= \sum_n Ca_{g,Rn-222,n}\ F_n\ DCF_{inh,Rn-222,n}\ BR_n \left(\sum_m PP_m\ t_{n,m} \right) + \qquad \text{Eq. 6.2-6}$$

$$+ \sum_{n=3}^{4} Ca_{g,Rn-222,e}\ f_{cooler}\ f_{use}\ DCF_{inh,Rn-222,n}\ BR_n \left(\sum_m PP_m\ t_{n,m} \right)$$

where

$D_{inh,\ g,\ Rn\text{-}222}$	=	annual dose from inhalation of ^{222}Rn decay products (Sv/yr)
$D_{inh,\ g,Rn\text{-}222,\ n}$	=	annual dose from inhalation of ^{222}Rn decay products for environment *n*
$Ca_{g,\ Rn\text{-}222,\ n}$	=	activity concentration of ^{222}Rn in air for environment *n*
$DCF_{inh,\ Rn\text{-}222,\ n}$	=	DCF for inhalation of ^{222}Rn decay products for environment *n* (Sv/Bq)
$Ca_{g,\ Rn\text{-}222,e}$	=	activity concentration of ^{222}Rn in indoor air at a high ventilation rate during evaporative cooler in operation.

This analysis develops values for the environment-dependent DCFs for inhalation of ^{222}Rn decay products, $DCF_{inh,\ Rn\text{-}222,\ n}$ (Section 6.5); the environment-dependent breathing rate, BR_n (Section 6.3); the amount of time population groups spend in defined environments, $t_{n,m}$ (Section 6.3); and the fraction of total population in specified population groups, PP_m (Section 6.3).

6.2.3 Evaluation of Ingestion Exposure

The total ingestion dose includes contributions from ingestion of water, crops, animal products, fish, and soil (BSC 2003 [160699], Section 6.4.9) and is expressed as

$$D_{ing,i} = D_{ing,w,i} + D_{ing,p,i} + D_{ing,d,i} + D_{ing,f,i} + D_{ing,s,i} \qquad \text{Eq. 6.2-7}$$

where

$D_{ing,\ i}$	=	annual dose from ingestion of radionuclide *i* (Sv/yr)
$D_{ing,\ w,\ i}$	=	annual dose from ingestion of radionuclide *i* in drinking water (Sv/yr)
$D_{ing,\ p,\ i}$	=	annual dose from ingestion of radionuclide *i* in crops (Sv/yr)
$D_{ing,\ d,\ i}$	=	annual dose from ingestion of radionuclide *i* in animal products (Sv/yr)
$D_{ing,\ f,\ i}$	=	annual dose from ingestion of radionuclide *i* in fish (Sv/yr)
$D_{ing,\ s,\ i}$	=	annual dose from inadvertent ingestion of radionuclide *i* in surface soil (Sv/yr)

Equation 6.2-7 can be further expressed (BSC 2003 [160699]; Sections 6.4.9.1, 6.4.9.2, 6.4.9.3, 6.4.9.5, and 6.4.9.4) as

$$D_{ing,i} = EDCF_{ing,i}\, Cw_i\, Uw + \sum_l \left[EDCF_{ing,l} \sum_j \left(Cp_{l,j}\, Up_j \right) \right] + \sum_l \left[EDCF_{ing,l} \sum_k \left(Cd_{l,k}\, Ud_k \right) \right] + \\ + EDCF_{ing,i}\, Cf_i\, Uf + \sum_l \left(EDCF_{ing,l}\, Cs_{m,l}\, Us \right)$$ Eq. 6.2-8

where

$EDCF_{ing,\,i}$	=	effective DCF for ingestion of radionuclide *i* (Sv/Bq)
Cw_i	=	activity concentration of radionuclide i in groundwater (Bq/L)
Uw	=	annual consumption rate of drinking water for the receptor (L/yr)
l	=	index of radionuclide decay chain member, $l = 0$ for primary radionuclide
$EDCF_{ing,\,l}$	=	effective dose coefficient for ingestion of radionuclide *l* in decay chain of primary radionuclide *i* (Sv/Bq)
$Cp_{l,\,j}$	=	activity concentration of a primary radionuclide *l* in crop type *j* (Bq/kg)
J	=	index of crop type, $j = 1$ for leafy vegetables, 2 for other vegetables, 3 for fruit, and 4 for grain
Up_j	=	annual consumption rate of crop type *j* (kg/yr)
$Cd_{l,\,k}$	=	activity concentration of primary radionuclide *l* in animal product type *k* (Bq/kg)
K	=	index of animal product, $k = 1$ for meat, 2 for poultry, 3 for milk, and 4 for eggs
Ud_k	=	annual consumption rate of animal product type *k* (kg/yr)
Cf_I	=	activity concentration of primary radionuclide *i* in fish (Bq/kg)
Uf	=	annual consumption rate of fish (kg/yr)
$Cs_{m,\,l}$	=	mass-based activity concentration of a primary radionuclide *l* in the surface soil (Bq/kg)
Us	=	annual consumption rate of soil (kg/yr)

This analysis develops values for the ingestion DCFs for individual radionuclides which are used to develop the effective DCFs for inhalation, $EDCF_{ing,l}$ (Section 6.5); the annual consumption rates of crops by crop type, Up_j (Section 6.4); the annual consumption rates of animal products by animal product type, Ud_k (Section 6.4); annual consumption rates of fish, *Uf* (Section 6.4); and the annual consumption rate of soil, *Us* (Section 6.4).

6.3 LIFESTYLE CHARACTERISTICS OF THE RECEPTOR

In this section, distributions for parameters in the biosphere model related to the lifestyle and physiological characteristics of the RMEI are developed. These parameters include population proportions, annual exposure time, breathing rates, the fraction of houses with evaporative coolers, and the evaporative cooler use factor.

6.3.1 Proportion of Population

Estimates of the proportion of the adult population in the Amargosa Valley classified into the four population groups (described in Section 6.2; PP_m, with m = population category) are used to estimate radiation exposure from inhalation and external exposure pathways.

Estimates of the proportion of the adult population in the Amargosa Valley within each of the four categories were developed from 2000 census data (Bureau of the Census 2002 [159728]) on employment (Tables 6.3-1 and 6.3-3) and commuting time (Table 6.3-2) of people in the Amargosa Valley census county division. The SE of the estimated proportions were calculated using methods recommended by the Bureau of the Census for calculating SE of percentages (Bureau of the Census 2002 [160179], pp. 8-6 and 8-21) as

$$SE(p) = DF\sqrt{\left(\frac{5}{N}\,p(1-p)\right)} \qquad \text{Eq. 6.3-1}$$

where

N	=	total population or population-group size
p	=	estimated proportion of the population in a group
DF	=	design factor.

The design factor is a state and characteristic-specific correction factor determined from the percent of the population sampled, which in the Amargosa Valley was 11.1% (Bureau of the Census 2002 [159728], Table P4). The associated design factors for Nevada are 1.3 for usual hours worked per week and weeks worked in 1999 and 1.4 for travel time to work and industry (Bureau of the Census 2002 [160179], Table C for Nevada).

With two exceptions, uniform distributions with a minimum one SE lower than the estimated proportion and a maximum one SE higher than the estimate are to be used in the biosphere model to define the proportion of non-workers, commuters, and local outdoor workers (Table 6.3-4). To account for uncertainty in the distribution of ash following a volcanic eruption, the lower bound of the distribution of commuters and the upper bound of the distribution of local outdoor workers are calculated as the estimated proportion plus or minus two SE. The proportion of local indoor workers is calculated in the model as one minus the sum of the three other proportions; the estimated proportion and SE for that group are presented below only for comparison.

Non-Workers–Non-workers are adults who are unemployed or not in the labor force, including retired persons. The number of non-workers was estimated based on information from the 2000 census on the work status during 1999 of Amargosa Valley residents ≥16 years old. Of an estimated total of 862 residents ≥16 years of age, 338 (39.2%) were not in the work force in 1999 (Table 6.3-1). The SE of this estimate is 4.8% (calculated as $1.3 \times [(5/862) \times 0.392 \times 0.608]^{1/2}$). The uniform distribution to be used in the biosphere model for this population group has minimum and maximum values of 34.4% and 44.0%, respectively (estimate proportion ± one SE). This distribution is to be used for the groundwater and volcanic ash exposure scenarios.

The estimated number of Amargosa Valley residents that worked differs between Table 6.3-1 (524 working residents) and Tables 6.3-2 and 6.3-3 (449 working residents). Table 6.3-1 summarizes employment status for all of 1999, the estimate of the total number of working residents includes people who worked part time. Tables 6.3-2 and 6.3-3 report information on commute time and industry of employment the week before survey forms were filled out (in April 2000), and therefore do not include information about people temporarily unemployed at that time. Because Table 6.3-1 includes information on part-time workers, and because information from that table is used in Section 6.3.2 to estimate the average number of hours worked, it is the more applicable source of information on the proportion of working (524 of 862 = 60.8%) and non-working (338 of 862 = 39.2%) residents. Estimates of the proportion of commuters and local outdoor workers are derived from information in Tables 6.3-2 and 6.3-3; therefore, these values must be multiplied by the percentage of the working population in 1999 (60.8%). To propagate errors from both estimates, the SE was calculated (using an equation modified from Knoll 1989 [161052], p. 90; Bureau of the Census 2002 [160179], p. 8-7) as

$$SE(p_1 p_2) = p_1 p_2 \sqrt{\frac{SE(p_1)^2}{p_1^{\;2}} + \frac{SE(p_2)^2}{p_2^{\;2}}} \qquad \text{Eq. 6.3-2}$$

where

p_1	=	estimated proportion of the population in a group 1 (the proportion of workers in the population)
p_2	=	estimated proportion of the population in group 2 (the proportion of commuters or local outdoor workers)

Table 6.3-1. Work Status of Amargosa Valley Residents in 1999

Working Time	Number of Males	Number of Females	Total
Worked in 1999	296	228	524
Usually worked ≥35 hours/week			
50–52 weeks	204	93	297
48–49 weeks	8	21	29
40–47 weeks		6	6
27–39 weeks	11	3	14
14–26 weeks	19	15	34
1–13 weeks	29		29
Usually worked 15-34 hours/week			
50–52 weeks		30	30
48–49 weeks	8	8	16
40–47 weeks		11	11
27–39 weeks		12	12
14–26 weeks		14	14
1–13 weeks	10	15	25
Usually worked 1–14 hours/week			
50–52 weeks	7		7
48–49 weeks			
40–47 weeks			
27–39 weeks			
14–26 weeks			
1–13 weeks			
Did not Work in 1999	165	173	338
Total	461	401	862

SOURCE: Bureau of the Census (2002 [159728], Table P47).

Commuters–This group includes employed people who work in uncontaminated areas. For the groundwater exposure scenario, it is assumed that this group includes all employed adults in the Amargosa Valley who commute 10 minutes or more one way to work (Section 5.1.1). An estimated 64.4% (289 of 449) of Amargosa Valley residents ≥16 years old that worked the week prior to census commuted 10 minutes or more (Table 6.3-2). The SE of this estimate is 7.1% (calculated as $1.4 \times [(5/449) \times 0.644 \times 0.356]^{1/2}$). This estimate must be multiplied by the proportion of the entire population ≥16 years old that was employed in 1999 (60.8%); thus, the estimate of adults in the Amargosa Valley that commute 10 minutes or more is 39.2% (i.e., 0.608×0.644), with a SE of 5.3% (calculated as $(0.608 \times 0.644) \times [(0.048^2/0.608^2) + (0.071^2/0.644^2)]^{1/2}$ using equation 6.3-2). The distribution of commuters for the groundwater exposure scenario is uniform with minimum and maximum values of 33.9% and 44.5%, respectively (estimated proportion ± one SE).

Table 6.3-2. Travel Time to Work for Amargosa Valley Residents

Travel Time (Minutes) [a]	Number of Residents
0 (Worked at home)	6
Less than 5	84
5 to 9	70
10 to 14	98
15 to 19	35
20 to 24	64
25 to 29	0
30 to 34	0
35 to 39	14
40 to 44	23
45 to 49	24
60 to 89	9
90 or more	22
Total	449

SOURCE: Bureau of the Census (2002 [159728], Table P31).

NOTE: [a] One-way commute time for employed residents ≥16 years old during the week prior to the April 2000 census.

For the volcanic ash exposure scenario, it is assumed that people who commute 35 minutes or more one way are not exposed to contaminated ash while at work (Section 5.1.1). An estimated 20.5% (92 of 449) Amargosa Valley residents ≥16 years old that worked the week prior to the census commuted 35 minutes or more (Table 6.3-2). The SE of this estimate is 6.0% ($1.4 \times [(5/449) \times 0.205 \times 0.795]^{1/2}$). The estimate of the total population of adults who commute ≥35 minutes is 12.5% (i.e., 0.608×0.205), with a SE of 3.8% ($(0.608 \times 0.205) \times [(0.048^2/0.608^2) + (0.060^2/0.205^2)]^{1/2}$). Because of uncertainty about where ash from a volcanic eruption at Yucca Mountain would fall (Section 5.1.1), the minimum value of the distribution of commuters is calculated as the estimated proportion minus two SE. Therefore, the distribution of commuters for the volcanic ash exposure scenario is uniform with minimum and maximum values of 4.9% and 16.3%, respectively.

Local Outdoor Workers–This group includes people who work outdoors and disturb (and therefore resuspend) contaminated soil. It is assumed that local outdoor workers include all agricultural works, 25% of construction workers, 10% of utility workers, and 10% of workers in the mining industry (Section 5.1.2). The estimated number of local outdoor workers in 2000 was 41 (26 agricultural workers, 2 of 7 construction workers, 1 of 8 utility workers, and 12 of 119 miners [Table 6.3-3]). This is 9.1% of the 449 Amargosa Valley residents ≥16 years old that worked the week prior to the census, with an SE of 4.2% ($1.4 \times ((5/449) \times 0.091 \times 0.909)^{1/2}$). The estimate of the total population of local outdoor workers is 5.5% (i.e., 0.608×0.091), with a SE of 2.6% ($(0.608 \times 0.091) \times [(0.048^2/0.608^2) + (0.042^2/0.091^2)]^{1/2}$).

Table 6.3-3. Industry of Employed Amargosa Valley Residents

Industry of Employment [a]	Number of Males	Number of Females	Total
Agriculture	26		26
Mining	101	18	119
Construction	7		7
Retail trade	19	14	33
Transportation and warehousing	23	26	49
Utilities	8		8
Educational services		47	47
Health care and social assistance	20	8	28
Arts, entertainment, recreation, accommodation, and food services	22	71	93
Other services (except public administration)	6	15	21
Public administration		18	18
Total	232	217	449

SOURCE: Bureau of the Census (2002 [159728], Table P49)

NOTES: [a] Industry of employed residents ≥16 years old during the week prior to the April 2000 census.

The distribution of local outdoor workers for the groundwater exposure scenario is uniform with a minimum of 2.9% and a maximum of 8.1% (estimated proportion ± one SE). Because of uncertainty about where ash from a volcanic eruption at Yucca Mountain would fall (Section 5.1.2), the maximum value of the distribution of this population group for the volcanic ash exposure scenario is calculated as the estimate plus two SE. Thus, the distribution of local outdoor workers for that exposure scenario is uniform with minimum and maximum values of 2.9% and 10.7%, respectively.

Local Indoor Workers–This group includes all people who work indoors (or outdoors in enclosed vehicles) in areas contaminated by groundwater or ash. In the biosphere model, the proportion of local indoor workers is calculated as one minus the sum of the other three population proportions. For the groundwater exposure scenario, the estimated proportion of local indoor workers is 16.1% (100% minus 39.2% non-workers, 39.2% commuters, and 5.5% local outdoor workers). For the volcanic ash exposure scenario, the estimated proportion in this group is 42.8% (100% minus 39.2% non-workers, 12.5% commuters, and 5.5% local outdoor workers).

The population proportion values are summarized in Table 6.3-4.

Table 6.3-4. Population Proportions

Group	Estimated Percentage	SE[a]	Uniform Distribution[b]	
			Minimum	Maximum
Groundwater Release Exposure Scenario				
Non-workers	39.2%	4.8%	34.4%	44.0%
Commuters	39.2%	5.3%	33.9%	44.5%
Local Outdoor Workers	5.5%	2.6%	2.9%	8.1%
Local Indoor Workers	16.1%[c]			
Volcanic Release Exposure Scenario				
Non-workers	39.2%	4.8%	34.4%	44.0%
Commuters	12.5%	3.8%	4.9%	16.3%
Local Outdoor Workers	5.5%	2.6%	2.9%	10.7%
Local Indoor Workers	42.8%[c]			

NOTES:
[a] Calculated using equations 6.3-1 and 6.3-2.
[b] Calculated as estimated percentage ± 1 SE, except volcanic–commuters (minimum = estimated percentage – 2 SE) and volcanic–local outdoor workers (maximum = estimated percentage + 2 SE).
[c] Calculated in the biosphere model as one minus the sum of the other three percentages.

6.3.2 Exposure Times

To calculate exposure times for the five environments (Section 6.2), time spent conducted six activities (working, commuting, outdoors not working, active outdoors, sleeping, and away from the Amargosa Valley) is estimated in Section 6.3.2.1. The time estimates are then used to develop exposure times for each of the four population groups (Section 6.3.2.2).

6.3.2.1 Behavior Times

Time Spent Working–The average amount of time people spent working (of those who worked), and the associated SE, was calculated from census data on hours worked per week and weeks worked per year by Amargosa Valley residents ≥16-year-old in 1999 (Table 6.3-5). The average of this categorical data set was calculated (using equations recommended by the Bureau of the Census 2002 [160179], p. 8-8 and 8-9) as

$$\bar{x} = \sum_{j}^{c} p_j m_j \qquad \text{Eq. 6.3-3}$$

where

c = number of categories into which the data is divided
p_j = portion of the total number of workers in category j
m_j = midpoint of each category j.

The Bureau of the Census (2002 [159728], Table P47) presents time worked as a combination of hours worked per week and weeks worked per year. These distributions were combined to estimate the number of hours worked in 1999. The estimated mean of the combined distributions was used as m_j in Equation 6.3-3, rather than the midpoint of each category. The mean was calculated as the product of the midpoints of hours per week and hours per year (Table 6.3-5) for each category, based on an equal probability of occurrence (i.e., uniform distribution) of each value within a category. This was done because the midpoint overestimates the average number of hours worked per year unless there is a correlation between number of hours worked per week and weeks worked per year. The SE was calculated (Bureau of the Census 2002 [160179], p. 8-8) as

$$SE(\bar{x}) = \sqrt{\frac{5}{N} \times s^2} \times DF \qquad \text{Eq. 6.3-4}$$

with DF = 1.3 (Bureau of the Census 2002 [160179], Table C for Nevada) and s^2 calculated as

$$s^2 = \sum_{j=1}^{c} p_j {m_j}^2 - (\bar{x})^2 \qquad \text{Eq. 6.3-5}$$

The average number of hours worked in 1999 by employed residents of the Amargosa Valley ≥16 years old was 1,994.5 hours/year, with a SE of 116.7 hours (Table 6.3-5). This is an annual average of 5.5 hours per day (1,994.5 hours/year ÷ 365 days/year), with a SE of 0.3 hours. Converted to hours worked per week (1,994.5 ÷ 52 weeks = 38.4 hours/week), this is similar to the national average number of hours worked by persons in all industries (39.7 hours; Bureau of the Census 2001 [160177], Table 582).

Time Spent Commuting–The average amount of time people that work spend commuting was calculated based on assumptions about how long it would take to drive out of the contaminated area (Section 5.1.1) and from census data on commuting time of ≥16-year-old residents of the Amargosa Valley the week prior to the 2000 census (Tables 6.3-6 and 6.3-7). Averages and SE are calculated using equations 6.3-3, 6.3-4, and 6.3-5, with a DF = 1.4 (Bureau of the Census 2002 [160179], Table C for Nevada).

For the groundwater scenario, it is assumed that persons who commute ≥10 minutes one way work outside of the area contaminated by groundwater (Section 5.1.1). The average round-trip commute time outside of contaminated areas for 289 Amargosa Valley residents ≥16 years old that commuted ≥10 minutes the week prior to the 2000 census was 46 minutes, with an SE of 12 minutes (Table 6.3-6). Based on an average work day of 8 hours (selected because 409 of 524 persons worked ≥35 hours per week, Table 6.3-5), the average number of days worked per year is 249 (average of 1,995 hours worked per year [Table 6.3-5] divided by 8 hours per day). The total annual commute time outside of the contaminated area is 11,454 minutes per year (i.e., 46 minutes × 249 days), or 31 minutes per day. The annualized SE of this estimate is 8 minutes (i.e., [12 minutes/day worked] × [249 days worked/year] ÷ [365 days/year]). For use in the model, this estimate is rounded to 0.5 ± 0.1 hours per day.

Table 6.3-5. Estimated Number of Hours Worked per Year

Weeks Worked/Year [a]		Hours Worked/Week [a]		m_j [b]	Number of Workers	p_j [c]	p_jm_j	$p_jm_j^2$
Range	Midpoint	Range	Midpoint					
50-52	51	≥35	52.5[d]	2,677.5	297	0.567	1,517.6	4,063,349.0
48-49	48.5	≥35	52.5[d]	2,546.3	29	0.055	140.9	358,813.5
40-47	43.5	≥35	52.5[d]	2,283.8	6	0.011	26.1	59,719.6
27-39	33	≥35	52.5[d]	1,732.5	14	0.027	46.3	80,194.3
14-26	20	≥35	52.5[d]	1,050.0	34	0.065	68.1	71,536.3
1-13	7	≥35	52.5[d]	367.5	29	0.055	20.3	7,474.5
50-52	51	15-34	24.5	1,249.5	30	0.057	71.5	89,384.6
48-49	48.5	15-34	24.5	1,188.3	16	0.031	36.3	43,112.6
40-47	43.5	15-34	24.5	1,065.8	11	0.021	22.4	23,843.6
27-39	33	15-34	24.5	808.5	12	0.023	18.5	14,969.6
14-26	20	15-34	24.5	490.0	14	0.027	13.1	6,414.9
1-13	7	15-34	24.5	171.5	25	0.048	8.2	1,403.3
50-52	51	1-14	7.5	382.5	7	0.013	5.1	1,954.5
Sum					524	1.000	1,994.5	4,822,170.1
Average [e]								1,994.5
s^2 [f]								844,117.0
SE [g]								116.7

SOURCE: Bureau of the Census (2002 [159728], Table P47).

NOTES:

[a] Estimated number of hours worked in 1999 by employed residents of the Amargosa Valley.

[b] m_j = midpoint of (weeks worked per year) × (midpoint of hours worked per week).

[c] p_j = portion of total workers (524) in category *j*.

[d] Calculated as (3/2) × (lower limit of interval), as recommended by Bureau of the Census (2002 [160179], p. 8-9).

[e] Calculated using equation 6.3-3.

[f] Calculated using equation 6.3-5.

[g] Calculated using equation 6.3-4, with DF = 1.3

For commuters, the round-trip commute time inside the area contaminated by groundwater is 20 minutes. This equals an annual average of 14 minutes per day, or 0.2 hours per day ([20 minutes/day worked] × [249 days worked/year] ÷ [365 days/year]). Because all commuters must travel at least that amount of time, no measure of variance is associated with this estimate.

For non-commuters (i.e., those who commute less than 10 minutes one way), the average round-trip commute within the area contaminated by groundwater is 9 minutes, with an annualized SE of less than 1 minute (Table 6.3-6). This equals an annual average of 6 minutes per day, or 0.1 hours per day ([9 minutes/day] × [249 days worked/year] ÷ [365 days/year]). Because the SE of this measure is small, no measure of variance is associated with this estimate.

Table 6.3-6. Commute Time for the Groundwater Exposure Scenario

Travel Time [a]	Non-Commuters					Commuters				
	N [b]	m_j [c]	P_j [d]	$p_j\, m_j$	$p_j m_j^2$	N [b]	m_j [e]	p_j [d]	$p_j\, m_j$	$p_j m_j^2$
0	6	0	0.04	0.00	0.00					
<5	84	5	0.53	2.63	13.13					
5-9	70	14	0.44	6.13	85.75					
10-14						98	4	0.34	1.36	5.43
15-19						35	14	0.12	1.70	23.74
20-24						64	24	0.22	5.31	127.56
25-29						0	34	0.00	0.00	0.00
30-34						0	44	0.00	0.00	0.00
35-39						14	54	0.05	2.62	141.26
40-44						23	64	0.08	5.09	325.98
45-59						24	84	0.08	6.98	585.97
60-89						9	129	0.03	4.02	518.23
>90 [f]						22	250	0.08	19.03	4,757.79
Sum	160		1.00	8.75	98.88	289		1.00	46.10	6,485.94
Average [g]					8.75					46.10
S^2 [h]					22.31					4,360.70
SE [i]					1.17					12.16

SOURCE: Bureau of the Census (2002 [159728], Table P31)

NOTES:
[a] One-way travel time to work in minutes.
[b] N = number of workers ≥16 years old within each travel-time category the week before the 2000 census.
[c] m_j = midpoint of total daily travel time in areas contaminated by groundwater, calculated as twice the midpoint of the one-way travel time interval.
[d] p_j = proportion of total workers in each category (160 non-commuters and 289 commuters).
[e] m_j = midpoint of total daily travel time in areas not contaminated by groundwater, calculated as twice the midpoint of the one-way travel time interval minus 20 minutes travel time in contaminated areas.
[f] midpoint of one-way travel time calculated as (3/2) × (lower limit of interval), as recommended by Bureau of the Census (2002 [160179], p. 8-9)
[g] Calculated using equation 6.3-3.
[h] Calculated using equation 6.3-5.
[i] Calculated using equation 6.3-4, with DF = 1.4.

For the volcanic ash exposure scenario, it is assumed that all persons who commute ≥35 minutes one way work outside of the area contaminated by ash (Section 5.1.1). The average round-trip commute time outside of the contaminated area for 92 Amargosa Valley residents ≥16 years old that commuted ≥35 minutes the week prior to the 2000 census was 69 minutes, with an SE of 25 minutes (Table 6.3-7). Based on an average work day of 8 hours, the total annual commute time outside of the contaminated area is 17,181 minutes per year (i.e., 69 minutes × 249 days), or 47 minutes per day. The SE of this estimate is 17 minutes (i.e., 25 minutes/day worked × 249 days worked/year ÷ 365 days/year). For use in the model, this estimate is rounded to 0.8 ± 0.3 hours per day.

Table 6.3-7. Commute Time for the Volcanic Ash Exposure Scenario

Travel Time [a]	Non-Commuters					Commuters				
	N [b]	m_j [c]	P_j [d]	$p_j\, m_j$	$p_j m_j^2$	N [b]	M_j [e]	p_j [d]	$p_j\, m_j$	$p_j m_j^2$
0	6	0	0.02	0.00	0.00					
<5	84	5	0.24	1.18	5.88					
5-9	70	14	0.20	2.75	38.43					
10-14	98	24	0.27	6.59	158.12					
15-19	35	34	0.10	3.33	113.33					
20-24	64	44	0.18	7.89	347.07					
25-29	0	54	0.00	0.00	0.00					
30-34	0	64	0.00	0.00	0.00					
35-39						14	4	0.15	0.61	2.43
40-44						23	14	0.25	3.50	49.00
45-59						24	34	0.26	8.87	301.57
60-89						9	79	0.10	7.73	610.53
>90 [f]						22	200	0.24	47.83	9,565.22
Sum	357		1.00	21.73	662.83	92		1.00	68.53	10,528.75
Average [g]					21.73					68.53
S^2 [h]					190.59					5,832.03
SE [i]					2.29					24.92

SOURCE: Bureau of the Census (2002 [159728], Table P31)

NOTES:

[a] One-way travel time to work in minutes.
[b] N = number of workers ≥16 years old within each travel-time category the week before the 2000 census.
[c] m_j = midpoint of total daily travel time in areas contaminated by volcanic ash.
[d] p_j = proportion of total workers in each category (357 non-commuters and 92 commuters).
[e] m_j = midpoint of total daily travel time in areas not contaminated by volcanic ash, calculated as twice the midpoint of the one-way travel time interval minus 70 minutes travel time in contaminated areas.
[f] midpoint of one-way travel time calculated as (3/2) × (lower limit of interval), as recommended by Bureau of the Census (2002 [160179], p. 8-9)
[g] Calculated using equation 6.3-3.
[h] Calculated using equation 6.3-5.
[i] Calculated using equation 6.3-4, with DF = 1.4.

For the volcanic ash scenario, commuters are assumed to spend 70 minutes per round trip travelling within the contaminated area. Based on an average work day of 8 hours, this is 48 minutes, or 0.8 hours per day (70 minutes per trip × 249 trips) ÷ 365 days/year). No variation is associated with this value because it is assumed that commuters drive at least that long to their place of work.

The average commute time for workers in the Amargosa Valley that commuted ≤35 minutes is 22 minutes, with an SE of 2 minutes (Table 6.3-7). Based on an average work day of 8 hours, this is 15 minutes, or 0.3 hours per day (22 minutes per trip × 249 trips) ÷ 365 days/year). Because the SE of this estimate is small, it is not incorporated into calculations of activity budgets.

Time Spent Outdoors Not Working– Based on information from the NHAPS (Klepeis et al. 1996 [159299], EPA 1997 [116135]), it is estimated that the average amount of time people in the Amargosa Valley spend outdoors in their community while not at work is 1.5 hours per day, with a SE of 0.2 hours per day.

For the 1992 to 1994 NHAPS survey, more than 9,000 people nationwide recorded their activities and locations during a 24-hour period; 6,059 people surveyed were 18 through 64 years old, and 1,349 were ≥65 years old (Klepeis et al. 1996 [159299], Table 3-9). Weighted percentages of time spent in various environments (Table 6.3-8) were calculated based on national population characteristics, season, day of week, and other factors (Klepeis et al. 1996 [159299], Table 6-1). Note that there is a mistake in the presentation of age groups in Chapter 6 of Klepeis et al. (1996 [159299]). The tables incorrectly divide the population into the age groups 0–4, 5–7, 17–64, and 65+. The correct age groups, as used elsewhere in the report (e.g., Klepeis et al. 1996 [159299], p. 4-4), are 0–4, 5–17, 18–64, and 65+.

Klepeis et al. (1996 [159299], Table 6-1) classified time spent outdoors per age group into categories (residential outdoors, near a vehicle, and other outdoors). For this analysis, time spent in these categories was weighted by the percentage of Amargosa Valley residents in each age group during 2000 (721 people 18 through 64 years old, 109 people ≥ 65 years old, Table 6.3-9).

Table 6.3-8. Weighted Average Amount of Time Spent per Day in Various Locations

Location [a]	18-64 Years Old				≥65 Years Old			
	%[b]	Minutes	SE [c]	n [d]	%[b]	Minutes	SE [c]	n [d]
Residential Indoors	64.71	932	3.5	6022	80.84	1164	6.2	1348
Residential Outdoors	2.93	42	3.6	1809	4.48	65	7.5	502
In Vehicle	6.43	93	1.5	5286	4.17	60	3.1	907
Travel/Near Vehicle	2.06	30	4.0	1787	0.99	14	4.6	342
Other Outdoor	2.33	34	7.3	858	1.27	18	16.6	118
Office/Factory	8.42	121	5.2	1749	1.18	17	16.9	132
Mall/Other Store	2.77	40	3.6	1871	1.89	27	4.4	397
Public Bldg.	5.19	75	5.4	1653	2.83	41	6.6	385
Bar/Restaurant	2.43	35	3.4	1718	1.27	18	5.5	270
Other Indoor	2.74	39	8.1	903	1.07	15	14.1	128

SOURCES: Klepeis et al. (1996 [159299], Table 6-1); EPA (1997 [116135], Tables 15-131 through 15-140)
NOTES:
[a] Locations defined in Klepeis et al. (1996 [159299], Tables 5-2 and 5-3).
[b] Average percentage of time spend in an environment, weighted based on national population characteristics.
[c] SE (minutes) for those that spent time in the location on day surveyed, from EPA (1997 116135], Tables 15-131 through 15-140); note that SE for entire population may be much smaller.
[d] Sample size for SE calculation (i.e., number of people 18 to 64 years old and ≥65 years old surveyed that spent time in a location on the day surveyed; from EPA (1997 [116135], Tables 15-131 through 15-140)).

Table 6.3-9. Age (years) of Residents of the Amargosa Valley

Age	Number of People	Age	Number of People	Age	Number of People
Under 1	13	17	13	45 to 49	108
1 and 2	27	18	39	50 to 54	96
3 and 4	17	19	0	55 to 59	67
5	0	20	16	60 and 61	38
6	8	21	0	62 to 64	22
7 to 9	41	22 to 24	49	65 to 69	37
10 and 11	72	25 to 29	8	70 to 74	36
12 and 13	28	30 to 34	66	75 to 79	24
14	9	35 to 39	127	80 to 84	6
15	65	40 to 44	85	85 and over	6
16	19				

SOURCE: Bureau of the Census (2002 [159728], Table P8).

1. **Residential Outdoors**–This category includes time spent at a pool, spa, yard, or other time outside one's own house or another house (Klepeis et al. 1996 [159299], Tables 5-2 and 5-3). The weighted percentage of time spent in this environment for respondents 18 through 64 years old and ≥65 years old was 2.93% and 4.48%, respectively (Table 6.3-8). Based on the proportion of people in the Amargosa Valley within each age group, the combined average time spent outdoors for all people ≥18 years old is 3.13% ([2.93% × 721 + 4.48% × 109]/830), or 0.75 hours per day.

2. **Traveling/Near Vehicle (Outdoors)**–This category includes time spent on a motorcycle, moped, or scooter; walking; on a bicycle or skateboard; in a stroller or carried by an adult; waiting for a bus, train, or other ride; on a sidewalk, street, or neighborhood; and at a parking lot, service station, or construction site (Klepeis et al. 1996 [159299], Tables 5-2 and 5-3). The weighted percentage of time spent in this environment for respondents 18 through 64 years old and ≥65 years old was 2.06% and 0.99%, respectively (Table 6.3-8). Based on the proportion of people in the Amargosa Valley within each age group, the combined average time spent outdoors for all people ≥18 years old is 1.92% ([2.06% × 721 + 0.09% × 109]/830), or 0.46 hours per day.

3. **Other Outdoors**–The other outdoor category includes time spent in a variety of places, such as school grounds, playgrounds, sports stadiums, parks, golf courses, pools, rivers, lakes, outdoor restaurants, picnic areas, and farms (Klepeis et al. 1996 [159299], Tables 5-2 and 5-3). The weighted percentage of time spent in these environments for respondents 18 through 64 years old and ≥65 years old was 2.33% and 1.27%, respectively (Table 6.3-8). Based on the proportion of people in the Amargosa Valley within each age group, the combined average time spent outdoors for all people ≥18 years old is 2.19% ([2.33% × 721 + 1.27% × 109]/830), or 0.53 hours per day.

The total time spent in these three environments by people ≥18 years old (weighted by the proportion of people in the Amargosa Valley 18–64 and ≥65 years old) is 7.24%, or 1.74 hours per day. A slightly lower value of 6.25%, or 1.5 hours per day, is selected for use in the biosphere model as the average time spent outdoors not working because some of the locations included in the environments are uncommon in the Amargosa Valley (e.g., bus and train stations, sports stadiums) and others are work sites included in other biosphere-model environments (e.g., construction sites and farms).

There is uncertainty associated with the use of these data, primarily because they come from a national survey. People in the rural Amargosa Valley may spend more time outdoors than people in urban areas. In contrast, they may spend less time outdoors, especially during the summer, because of extreme temperatures. In addition, there are slight regional differences in the data that cannot be considered in this analysis because weighted, age-specific results are not presented by region (Klepeis et al. 1996 [159299], Table 6-1). There also is uncertainty about whether these categories includes all likely non-work time spent outdoors in the Amargosa Valley area.

The only estimates of variation presented for the NHAPS data are for the subsamples of people who spent time in an environment, or "doers" (EPA 1997 [116135], Table 15-131 through 15-140). For example, the SE of time spent at home in the residential outdoor environment, for those doers who spent time in that environment, was 3.6 minutes (n = 1,809) for ages 18 through 64 and 7.5 minutes (n = 502) for those ≥65 years old (Table 6.3-8) (EPA 1997 [116135], Table 15-132). The remaining approximately 5,100 people surveyed (total sample of 6,059 + 1,349 minus subsample sizes of 1,809 + 502, Klepeis et al. 1996 [159299], Table 3-9) spent no time in that environment on the day surveyed. The SE for the entire sample would be at least a factor of two smaller because total sample sizes are about four times larger than subsample sizes (compare the square root of 1,801 to the square root of 6,059). Adding 5,100 more responses, all of which have the same value (zero), would further decrease the estimate of variation. Therefore, the SEs calculated for doers are bounding or extreme estimates of variation around the mean time spent in an environment. The combined bounding estimate of SE for the three environments for persons 18-64 years old, calculated as the square root of the sum of the squared SE for each environment (Knoll 1989 [161052], p. 88) is 9.1 minutes ($[3.6^2 + 4.0^2 + 7.3^2]^{½}$), or 0.15 hours. The combined estimates for persons ≥65 years old is 18.8 minutes, or 0.31 hours. Weighted by the age of people in the Amargosa Valley, the estimate for all persons ≥18 years old is 0.2 hours ($[0.15 \times 721 + 0.31 \times 109]/830$).

The bounding estimate of SE, 0.2 hours, based on variation among those who spent time in an environment, is selected for use in the biosphere model. This high value is selected to account for uncertainty in the application of national data on activity budgets to the population in the Amargosa Valley. In summary, an average of 1.5 hours per day outdoors not working, with a SE of 0.2 hours, is selected as the estimate of total time spent outdoors while not working.

Time Spent Active Outdoors–Based in part on information in a 1985 national survey of activity budgets (EPA 1997 [116135], p. 15-3), it is estimated that an average of 20% of time spent outdoors in contaminated areas is spent conducting dust-generating activities and that local outdoor workers spend an average of 50% of their work time conducting dust-generating activities.

Table 6.3-10 shows the average amount of time that over 5,000 people surveyed nationwide in 1985 (an early version of the NHAPS) spent in the "physical/outdoor" environment and the "other/outdoor" environment, when they spent time in those environments. The percent of total time outdoors spent in physical activity ranged from 10 to 33% per age group (from EPA 1997 [116135], Table 15-10). Based on the proportion of people in the Amargosa Valley within each age group (Table 6.3-9), the combined average time spent conducting physical activity while outdoors is 20.1%. This value at least bounds, and most likely overestimates, the amount of time people spend conducting dust-generating activities outdoors because it includes time spent conducting activities that resuspend little or no excess soil (e.g., walking, golfing, and swimming) and it includes activities that would be conducted away form contaminated areas. A proportion of 20%, and a relatively large SE of 0.1 hours (half of the SE of the total time spent outdoors not working), is selected for the biosphere model to account for uncertainty in the application of this 1985 national data to conditions in the Amargosa Valley. Thus, an average time of 0.3 ± 0.1 hours (20% of 1.5 hours spent outdoors while not at work) spent active outdoors and 1.2 ± 0.2 hours spent inactive outdoors while not working is to be used for all population groups.

It is not reasonable to conclude that local outdoor workers would spend all of their work hours conducting dust-generating activities. Although some workers may spend the majority of their work time conducting dust-generating activities, others would spend little time doing so. For example, some farm workers may spend a substantial amount of their time irrigating, spraying pesticides, and conducting other activities that resuspend little soil. Many miners and other outdoor workers would be involved in activities that do not resuspend surface soil. Therefore, a value of 50% was chosen as a reasonable estimate of the percentage of time that outdoor workers spend conducting dust-generating activities. This is 2.8 hours of an average of 5.5 hours spent working per day. An SE of 0.2 hours (more than half of the total SE of time spent working) is selected to account for uncertainty in time spent conducting dust-disturbing activities. Local outdoor workers spend the remainder of their work time (2.7 ± 0.2 hours) in the inactive outdoor environment.

Time Spent Sleeping–Based on NHAPS data, the average amount of time people in the Amargosa Valley spend sleeping is estimated to be 8.3 hours per day with a SE of 0.1 hours.

Table 6.3-10. Average Minutes Spent Active and Inactive Outdoors by Age Groups in 1985

Environment	18–24 Years	25–44 Years	45–64 Years	≥ 65 Years
Physical/Outdoors	17	19	7	15
Other/Outdoors	34	48	60	82
Total Outdoors	51	67	67	97
% Outdoor Physical	33.3%	28.4%	10.4%	15.5%
Number of Amargosa Valley Residents [a]	104	286	331	109

SOURCE: EPA (1997 [116135], Table 15-10).
NOTES: [a] From Table 6.3-9.

People 18 through 64 years old surveyed for NHAPS spent an average of 497 minutes (8.3 hours) sleeping or napping (SE = 1.6 minutes or 0.03 hours) (EPA 1997 [116135], Table 15-83). People ≥ 65 years old slept or napped an average of 517 minutes (8.6 hours) (SE = 3.2 minutes or 0.05 hours). These statistics were calculated using data from people who spent time sleeping or napping during the 24-hour period they were surveyed. However, because most people slept or napped at some time during the survey (6,041 of 6,059 people 18 through 64 years old and 1,347 of 1,349 people ≥ 65 years old) (EPA 1997 [116135], Table 15-83) the values do not need to be adjusted to account for those not sleeping or napping. Total sample sizes are from Klepeis et al. (1996 [159299], Table 3-9).

Based on the proportion of people in the Amargosa Valley within each age group, the combined average time spent sleeping for all people ≥ 18 years old is 8.3 hours ([496.9 × 721 + 517.1 × 109] ÷ 830 ÷ 60 minutes). A SE of 0.1 hours, which is larger than those reported in the study, is selected to account for uncertainty in the application of this data to the population in the Amargosa Valley.

Time Spent Away from the Amargosa Valley–Based on NHAPS data and characteristics of the Amargosa Valley, it is estimated that people in the Amargosa Valley spend an average of 2.0 hours per day, with a SE of 0.4 hours per day, out of the Amargosa Valley shopping, on vacation, getting medical attention, or conducting other non-work activities.

The Amargosa Valley holds a small community with only a small medical clinic and a few stores, restaurants, entertainment opportunities, or other amenities. It is therefore reasonable to conclude that adults spend some time out of the Amargosa Valley obtaining goods and services and while on vacation.

The combined, weighted average percentage of time people 18 through 64 and ≥ 65 years of age surveyed for the NHAPS spent in stores, public buildings (including schools, churches, medical facilities), bars and restaurants, and other indoor locations was 13.13% (3.2 hours) and 7.06% (1.7 hours), respectively (Table 6.3-8). Although some facilities included in these categories are found in the Amargosa Valley (e.g., elementary school, churches, small grocery stores, small medical clinic, and a few restaurants), many activities associated with these locations occur outside of the community. The nearest locations to find large shops and larger medical facilities are Pahrump and Las Vegas, which are 0.5 to more than 1 hour away; therefore, most trips will require 2 or more hours.

It is likely that all residents spend some time outside the Amargosa Valley each year on vacation, recreating, or traveling for other reasons. A seven-day trip is about 1.9% of a year, or an average of 0.46 hours per day.

To account for the time people spend out of the farming and residential community for entertainment; vacation; and to obtain medical attention, goods, and other services, it is estimated that residents would spend an average of 2 hours per day out of the potentially contaminated area, with a SE of 0.4 hours. This relatively large SE was selected to account for uncertainty in applying national data to the behavior of residents of the Amargosa Valley and to account for uncertainty in the size of the area contaminated by volcanic ash (and therefore the amount of time it would take to leave that area).

6.3.2.2 Exposure Times per Population Group

The following is a summary of the exposure times per population group, based on the information in Sections 6.3.2.1. Lognormal distributions of exposure times are to be used, with minimum and maximum values equal to the upper and lower 99th percentile of the distributions. The arithmetic means and SE of these distributions are described below, and the distributions are summarized in Table 6.3-11.

Lognormal distributions are recommended because population distributions of exposure times generally are characterized by most people spending little time conducting an activity or in a location and a few people spending a large amount of time conducting that activity. For example, the average time spent outside the residence by 1,809 people ages 18 to 64 that spent time outside of a residence was 144 minutes, the median was 90 minutes, and the 75th, 90th, and 95th percentiles were 199, 360, and 470 minutes, respectively (EPA 1997 [116135], Table 15-132). About 4,000 other people surveyed spent no time outside of a residence.

For the lognormal distribution, the lower and upper bounds of the 99% confidence interval of the mean are calculated using formulas based on LaPlante and Poor (1997 [101079], p. 3-12), where the number of standard deviations for a 99% confidence interval is 2.576 (Lide and Frederikse 1997 [103178], p. A-104.), such that

$$\begin{aligned} lower\ bound &= \frac{GM}{GSD^{2.576}} \\ upper\ bound &= GM \times GSD^{2.576} \end{aligned} \qquad \text{(Eq. 6.3-6)}$$

where

GM	=	geometric mean
GSD	=	geometric standard deviation

The geometric mean (GM) and geometric standard deviation (GSD) are calculated as

$$GM = e^{\lambda}$$
$$GSD = e^{\zeta}$$

with the variance of ln(x) for the lognormal distribution, ζ, given by Golder Associates (2000 [146973], p. B-3), as

$$\zeta^2 = \ln\left[1 + \left(\frac{SE}{\overline{X}}\right)^2\right] \qquad \text{Eq. 6.3-7}$$

and the expected value of ln(x), λ, is

$$\lambda = \ln(\overline{X}) - \frac{1}{2}\zeta^2 \qquad \text{Eq. 6.3.8}$$

For cases in which more than one activity must be summed to obtain an average time (e.g., total time out of the contaminated environment includes commuting time and time spent away from the Amargosa Valley), the SE of the total average time is calculated as the square root of the sum of squared SE values per activity (Knoll 1989 [161052], p. 88).

Non-Workers–Non-workers spend an average of 2.0 ± 0.4 hours per day out of the potentially contaminated area conducting non-work activities, 0.3 ± 0.1 hours per day active outdoors, 1.2 ± 0.2 hours per day inactive outdoors conducting non-work activities, and 8.3 ± 0.1 hours sleeping. The average time spent indoors by non-workers is 12.2 hours per day (24 hours minus 2.0 hours away, 0.3 hours active outdoors, 1.2 hours inactive outdoors, and 8.3 hours sleeping).

Commuters–For the groundwater scenario, commuters spend an average of 8.0 ± 0.5 hours per day out of the contaminated area, including time spent working (5.5 ± 0.3 hours per day), commuting (0.5 ± 0.1 hours per day), and conducting non-work activities (2.0 ± 0.4 hour per day), with the SE calculated as $[0.3^2 + 0.1^2 + 0.4^2]^{½} = 0.51$. Commuters spend an average of 0.3 ± 0.1 hours per day active outdoors. They spend an average of 1.4 ± 0.2 hours per day inactive in the outdoor environment, including 0.2 hours per day commuting within the area assumed to be contaminated by groundwater and an additional 1.2 ± 0.2 hours inactive outdoors while not working. It is estimated that commuters spend 8.3 ± 0.1 hours per day sleeping. The average time spent active indoors within the contaminated area is 6.0 hours per day (24 hours minus 8.0 hours away, 0.3 hours active outdoors, 1.4 hours inactive outdoors, and 8.3 hours sleeping).

For the volcanic ash scenario, commuters spend an average of 8.3 ± 0.6 hours per day out of the contaminated area, including time spent working (5.5 ± 0.3 hours per day), commuting (0.8 ± 0.3 hours per day), and conducting non-work activities (2.0 ± 0.4 hour per day), with the SE calculated as $[0.3^2 + 0.3^2 + 0.4^2]^{½} = 0.58$. They spend an average of 0.3 ± 0.1 hours per day active outdoors. They spend an average of 2.0 ± 0.2 hours per day inactive in the outdoor environment, including 0.8 hours per day commuting within the area assumed to be contaminated by ash, and an additional 1.2 ± 0.2 hours inactive outdoors while not working. It is estimated that commuters spend 8.3 ± 0.1 hours per day sleeping. The average time spent active indoors within the contaminated area is 5.1 hours per day (24 hours minus 8.3 hours away, 0.3 hours active outdoors, 2.0 hours inactive outdoors, and 8.3 hours sleeping).

Local Outdoor Workers–For the groundwater scenario, local outdoor workers spend an average of 2.0 ± 0.4 hours per day out of the potentially contaminated area conducting non-work activities. They spend 3.1 ± 0.2 hours per day active outdoors, including 2.8 ± 0.2 hours active outdoors while working and 0.3 ± 0.1 hours active outdoors conducting non-work activities. They spend an average of 4.0 ± 0.3 hour per day in the inactive outdoor environment, including 2.7 ± 0.2 hours working, 0.1 hours commuting, and 1.2 ± 0.2 hours conducting non-work activities. Local outdoor workers spend 8.3 ± 0.1 hours per day sleeping. Thus, the average time spent active indoors by local outdoor workers is 6.6 hours per day (24 hours minus 2 hours away, 3.1 hours active outdoors, 4.0 hours inactive outdoors, and 8.3 hours sleeping).

All exposure times are the same for the volcanic ash scenario except the time local outdoor workers commute (0.3 hours). Thus, they spend an average of 4.2 ± 0.3 hour per day in the inactive outdoor environment, and an average of 6.4 hours per day active indoors.

Local Indoor Workers–For the groundwater scenario, local indoor workers spend 2.0 ± 0.4 hours per day out of the contaminated area conducting non-work activities. They spend an average of 0.3 ± 0.1 hours per day active outdoors. They spend 1.3 ± 0.2 hour per day in the inactive outdoor environment, including 0.1 hours commuting and 1.2 ± 0.2 hours conducting non-work activities. Average time spent active indoors by local indoor workers is 12.1 hours (24 hours minus 2.0 hours away, 0.3 hours active outdoors, 1.3 hours inactive outdoors, and 8.3 hours sleeping). This estimate of 12.1 hours includes an average of 5.5 hours working indoors.

Table 6.3-11. Daily Exposure Times for Amargosa Valley Population Groups

Population Group	Groundwater Scenario [a]				Volcanic Ash Scenario [a]			
Environment	**AM**	**SE**	**Min [b]**	**Max [b]**	**AM**	**SE**	**Min [b]**	**Max [b]**
Non–Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.2	0.2	0.8	1.8	1.2	0.2	0.8	1.8
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors [c]	12.2				12.2			
Commuters								
Away	8.0	0.5	6.8	9.4	8.3	0.6	6.9	10.0
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.4	0.2	1.0	2.0	2.0	0.2	1.5	2.6
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors [c]	6.0				5.1			
Local Outdoor Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	3.1	0.2	2.6	3.7	3.1	0.2	2.6	3.7
Inactive Outdoors	4.0	0.3	3.3	4.8	4.2	0.3	3.5	5.0
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors [c]	6.6				6.4			
Local Indoor Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.3	0.2	0.9	1.9	1.5	0.2	1.1	2.1
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors [c]	12.1				11.9			

NOTES: AM = arithmetic mean.

[a] The statistics for the exposure scenario include arithmetic mean, SE, minimum, and maximum values defining the lognormal distributions of exposure times.

[b] Calculated using equation 6.3-6.

[c] Calculated as 24 hours minus all other estimates for a population group; therefore, no SE or bounds are presented.

All exposure times are the same for the volcanic ash scenario except for the time local indoor workers commute (0.3 hours). Thus, they spend an average of 1.5 ± 0.2 hour per day in the inactive outdoor environment and an average of 11.9 hours per day active indoors.

6.3.3 Breathing Rates

Breathing rates used in the biosphere model represent the average values for each population group within the five environments used in the ERMYN model (Section 6.2). The breathing rate for a population group in an environment is determined by considering the fraction of time people in that group are involved in various levels of activity and the breathing rate associated with those activity levels. Uncertainty in breathing rates is associated with the accuracy of estimates of activity levels for each population group and with the accuracy of measurements of breathing rates for these activity levels (ICRP 1994 [153705], p. 198).

The expected values of breathing rates for the biosphere model were developed using values from ICRP Publication 66 (ICRP 1994 [153705]). The activity levels considered in this analysis correspond to activity levels used in ICRP Publication 66: sleep, sitting, light exercise, and heavy exercise (ICRP 1994 [153705], p. 192). Light exercise corresponds to working, for example, in workshops, active housecleaning, painting, or woodworking. Heavy exercise is considered appropriate for construction workers, farm workers, firemen, and athletes. ICRP Publication 66 assigns a standard combination of activity levels to the typical groups of people and typical environments (ICRP 1994 [153705], p. 193).

Four environments in the contaminated area are considered in the biosphere model: active outdoors, inactive outdoors, active indoors (i.e., not sleeping) and asleep (Section 6.3.2). People from all four groups (Section 6.3.1) could spent some of their time in any of these environments, either working, recreating, doing house work, resting, or involved in other activities. To develop expected values of breathing rates for the biosphere model, the amount of time spent in various equivalent environments was taken from the recent ICRP recommendations in the respiratory tract model (ICRP 1994 [153705]), in which the nominal mix of activity levels associated with different environments is defined. These values were adopted for the environments used in the biosphere model as shown in Table 6.3-12.

The breathing rates in ICRP Publication 66 are calculated using the following mix of activity levels: 1/3 sitting + 2/3 light exercise for the time spent indoors not sleeping (corresponding to the active indoors environment of the biosphere model); 1/2 sitting + 3/8 light exercise + 1/8 heavy exercise for travel and sports; and 7/8 light exercise + 1/8 heavy exercise for outdoor workers (ICRP 1994 [153705], p. 197). In the biosphere model, the time spent recreating outdoors is divided into two environments, active and inactive. Therefore, the activity mix that corresponds to the ICRP travel and sports category was not used. Rather, the breathing rate associated with the outdoor workers (7/8 light exercise + 1/8 heavy exercise) was used for active recreation outdoors and the breathing rate associated with the active indoor environment (1/3 sitting + 2/3 light exercise) was used for the inactive recreation outdoors.

Table 6.3-12. Contributions of Activity Levels by Population Group and Environment

Population Group, Environment	Commuters	Local Outdoor Workers	Local Indoor Workers (Sedentary)	Non-workers
Active outdoors	At work: N/A	At work: 7/8 light exercise 1/8 heavy exercise	At work: N/A	At work: N/A
	Recreation/Other: 7/8 light exercise 1/8 heavy exercise	Recreation/Other: 7/8 light exercise 1/8 heavy exercise	Recreation/Other: 7/8 light exercise 1/8 heavy exercise	Recreation/Other: 7/8 light exercise 1/8 heavy exercise
Inactive outdoors	At work: N/A	At work: 1/3 sitting 2/3 light exercise	At work: N/A	At work: N/A
	Recreation/Other: 1/3 sitting 2/3 light exercise	Recreation/Other: 1/3 sitting 2/3 light exercise	Recreation/Other: 1/3 sitting 2/3 light exercise	Recreation/Other: 1/3 sitting 2/3 light exercise
Active indoors	At work: N/A	At work: N/A	At work: 1/3 sitting 2/3 light exercise	At work: N/A
	At home: 1/3 sitting 2/3 light exercise	At home: 1/3 sitting 2/3 light exercise	At home: 1/3 sitting 2/3 light exercise	At home: 1/3 sitting 2/3 light exercise
Asleep indoors	Sleeping	Sleeping	Sleeping	Sleeping

SOURCE: ICRP 1994 [153705] p. 193, Tables B.16B, and B.17

Activity-level dependent breathing rates for the biosphere model (Table 6.3-13) were calculated using data from ICRP Publication 66 (ICRP 1994 [153705]) and gender weights consistent with the 2000 Census results, that is, 52.2% for males 18 years old or older and 47.8% for females 18 years old or older (Bureau of the Census 2002 [159728], Table P8).

When the activity level information (Table 6.3-12) is combined with the breathing rates for the Amargosa Valley population (Table 6.3-13), the expected values of effective breathing rates for the population groups and for the environments can be calculated (Table 6.3-14).

Table 6.3-13. Breathing Rates per Level of Activity

Gender	Breathing Rate for a Given Exercise Level, m^3/hr			
	Sleep	Sitting	Light Exercise	Heavy Exercise
Adult woman	0.32	0.39	1.25	2.7
Adult man	0.45	0.54	1.5	3.0
Adult ICRP–Amargosa Valley [a]	0.39	0.47	1.38	2.86

SOURCE: ICRP 1994 [153705], p. 24

NOTES:

[a] Calculated by producing the weighted average of the breathing rates for males and females using the weights based on the fraction of males and females derived from the 2000 Census information (Bureau of the Census 2002 [159728], Table P8).

Table 6.3-14. Calculation of Expected Breathing Rates

Environment	Breathing Rate for All Population Groups [a]
Active outdoors	7/8 × 1.38 m^3/hr + 1/8 × 2.86 m^3/hr = **1.57 m^3/hr** [b]
Inactive outdoors	1/3 × 0.47 m^3/hr + 2/3 × 1.38 m^3/hr = **1.08 m^3/hr** [b]
Active indoors	1/3 × 0.47 m^3/hr + 2/3 × 1.38 m^3/hr = **1.08 m^3/hr** [b]
Asleep indoors	**0.39 m^3/hr**

NOTE: For the activity mix consisting of 1/2 (50%) time spent sitting, 3/8 (38%) in light exercise, and 1/8 (13%) in heavy exercise, which is recommended by ICRP (ICRP 1994 [153705], p. 197) for outdoor travel, sports, etc, the breathing rate would be 1.11 m^3/hr, which is practically the same as that the value calculated for the biosphere model for the inactive outdoors and active indoors environments.

[a] Commuters, local outdoor workers, local indoor workers, non-workers.

[b] The results were rounded off to 3 significant digits

The values of breathing rates shown in Table 6.3-14 are recommended for the use in the biosphere model.

The remainder of this section presents an evaluation of how the breathing rates calculated using the ICRP-recommended mix of activity levels compare with the breathing rates that would be obtained if the national survey data were used instead. The fractional contributions of activity levels listed in Table 6.3-12 were compared with the aggregated results of the national survey (Robin and Thomas 1991, as cited in EPA 1997 [116135], Table 15-9) listed in Table 6.3-15. The survey investigated the amount of time spent by people in various microenvironments. The time spent in various activities was divided between the environment-activity level categories as indicated in Table 6.3-15. The percentage of time spent in a given environment at a given activity level was then calculated by taking the weighted averages of the percent time spent on week days and on weekends with weighting factors corresponding to the number of week days and weekend days.

Table 6.3-16 compares the percent of time spent in various environments at different activity levels calculated from the national survey data (Table 6.3-15) with the values adopted for the biosphere model calculated based on ICRP recommendations (Table 6.3-12).

Table 6.3-15. Calculation of Aggregated Times Spent in Environments per Activity Level

Activity	Bin Code[a]	Weekday Minutes/Day	Weekend Minutes/Day [b]
Values for Individual Activities			
Autoplaces	2	3	3
Restaurant/bar	1	20	23
In vehicle	4	86	91
Physical/Outdoors	6	15	23
Physical/Indoors	3	8	9
Work/Study-Residence	1	16	15
Work/Study-Other	1	225	64
Cooking	2	35	34
Other Activities/Kitchen	2	73	73
Chores/Child	2	124	120
Shop/Errand	2	30	35
Other /Outdoors	5	51	67
Social/Cultural	1	62	99
Leisure-Eat/Indoors [c]	1	105.5	128.5
Leisure-Eat/Indoors [c]	2	105.5	128.5
Sleep/Indoors		481	525

Environment/Activity Level	Bin Code	Total minutes/day	Percent of Time	Total minutes/day	Percent of Time	Total hours/day [d]	Percent of Time
Aggregated Values							
		Weekday		Weekend		Average for the Week	
Indoor sitting	1	428.5	53%	329.5	45%	6.67	51%
Indoor light exercise	2	370.5	46%	393.5	54%	6.28	48%
Indoor heavy exercise	3	8	1%	9	1%	0.14	1%
Indoor total		807		732		13.09	
Outdoor sitting	4	86	57%	91	50%	1.46	55%
Outdoor light exercise	5	51	34%	67	37%	0.93	35%
Outdoor heavy exercise	6	15	10%	23	13%	0.29	11%
Outdoor total		152		181		2.67	
Sleep/Indoors		481	100%	525	100%	8.23	100%

SOURCE: EPA 1997 [116135], Table 15-9

NOTES:

The data are for sample population ages 12 years and older. The biosphere model applies to adults (18 years and older). However, these data are presented here for comparison only (not used to develop the values of model parameters) and are considered to sufficiently represent times spent in various activities for adult population.

[a] Bin code corresponds to the designation of activity level and environment used for aggregation.

[b] Weekend minutes do not add up to 1440 minutes per day due to rounding.

[c] Leisure-Eat/Indoors time was split evenly between indoor sitting and indoor light exercise categories.

[d] Weighted averages for a week.

Table 6.3-16. Percent of Time Spent Outdoors and Indoors per Activity Level

Environment	Activity Level			Breathing rate [a]	Reference
	Sitting	Light Exercise	Heavy Exercise		
Outdoors active	0%	87.5%	12.5 %	1.57 m^3/hr	Values adopted for the biosphere model based on ICRP 1994 [153705], pp. 24 and 197.
Outdoors inactive	33%	67%	0%	1.08 m^3/hr	Values adopted for the biosphere model based on ICRP 1994 [153705], pp. 24 and 197.
Outdoor active and inactive	55 % [b]	35 %	11 %	1.06 m^3/hr	Aggregated results based on Robin and Thomas 1991, as cited in EPA 1997 [116135], p. 15-27.
Indoors active	33 %	67 %	0%	1.08 m^3/hr	Values adopted for the biosphere model based on ICRP 1994 [153705], pp. 24 and 197.
	51 %	48 %	1 %	0.93 m^3/hr	Aggregated results based on Robin and Thomas 1991, as cited in EPA 1997 [116135], p. 15-27.
Asleep Indoors	N/A	N/A	N/A	0.39 m^3/hr	Values adopted for the biosphere model based on ICRP 1994 [153705], p. 24.

NOTES:

[a] Calculated using the breathing rates for adults of both genders from Table 6.3-13.

[b] The percentages do not add to 100% because of the rounding errors.

Compared with the results of the national survey, the values adopted for the biosphere model for the outdoor and indoor environments assume that less time is spent sitting and that more is spent at light or higher levels of activity. However, in terms of the breathing rates associated with the individual environments, the difference is slight (Table 6.3-16). For the outdoor environment, the national survey results were combined into one environment, while the biosphere model uses two outdoor environments. The results (Table 6.3-16) indicate that the values of breathing rates selected for the biosphere model are slightly more conservative than what would be suggested by the results of the national survey. However, there is some degree of ambiguity in determining the breathing rates corresponding to the aggregated results of the national survey because the aggregation of activities listed in Table 6.3-15 involved categorizing the listed activities into the indoor and outdoor categories and activity levels. Therefore, it is concluded that the values of the environment-specific breathing rates selected for the biosphere model appropriately describe the expected combination of exercise levels.

The breathing rate is a parameter related to human physiology, but the biosphere model does not directly consider human physiology. The receptor is defined as an adult who has physiological characteristics of an average adult person. The same concept is applied in dose assessments in regard to dosimetric models, which, for the purpose of radiological protection, use the standard representations of adult persons (e.g., ICRP 1979 [110386], Section 1). In this context, breathing rates characteristic of an average adult, as recommended in the ICRP Publication 66 (ICRP 1994 [153705]) and in conjunction with the standard activity mix discussed above (Table 6.3-14), are adequate for biosphere modeling.

6.3.4 Evaporative Cooler Use

There are two parameters in the biosphere model that quantify the use of evaporative coolers. These are the fraction of houses with evaporative coolers and the annual evaporative cooler use factor. For houses that are equipped with evaporative coolers, the evaporative cooler use factor is a fraction of a year that an evaporative cooler is used in a given house. The fraction of houses with evaporative coolers was developed based on the results of the 1997 regional survey (DTN: MO0106SPAECL02.016 [160256]). The evaporative cooler use factor was developed based on the meteorological monitoring data from the northern Amargosa Valley and Spokane, Washington.

6.3.4.1 Fraction of Houses with Evaporative Coolers

One of the questions asked during the regional food consumption survey (DOE 1997 [100332]) was: "Do you use a swamp cooler to cool your home during any part of the year?" Of 187 full time adult residents of the Amargosa Valley who participated in the survey, 138 (73.8%) responded yes, and 49 responded no. Therefore, the estimated proportion of households that used evaporative coolers is 0.738. This proportion was calculated using the information from the data set DTN: MO0106SPAECL02.016 [160256]. These calculations were performed using Excel (Attachment III, *Food Consumption Rates.xls*).

There were only two possible answers to this question (yes and no), so the binomial distribution was selected to represent uncertainty in the sampling results. The binomial distribution is generally applied when the result is one of a small number of possible final states (Bevington and Robinson 1992 [147076], p. 17), which fits the case of using an evaporative cooler. The biosphere model requires two inputs for a binomial distribution, the probability and a batch size. The probability is 0.738, based on 73.8% of people surveyed in Amargosa Valley having evaporative coolers) and the batch (sample) size is 187. The resulting distribution is presented in units of households, with a mean of 138 (187×0.738). Because the biosphere model uses the fraction of houses that used evaporative coolers rather than the number of houses, the sampled value must be divided by the batch size of 187.

6.3.4.2 Evaporative Cooler Use Factor

The proportion of a year that evaporative coolers are used was determined based on maximum daily temperatures (Tables 6.3-17 and 6.3-18). This information, rather than the results of the survey of Amargosa Valley residents (DOE 1997 [100332]), was used for the following reasons. First, the survey results are not precise because people were asked how many months, rather than days, a cooler was run. Second, the survey did not clarify whether respondents ran their cooler without water for part of the year. The fact that some respondents reported running their coolers for 10 to 12 months indicates that some respondents may have included the time that cooler fans were run with the water pump turned off to provide home ventilation. And third, there is no similar survey data that can be used to predict evaporative cooler use for the future climate.

The evaporative cooler use factor was calculated as the proportion of days per year that the daily maximum outside temperature exceeded a threshold level above which people were likely to cool their homes. Three threshold levels were used to account for uncertainty in the range of temperatures over which people are likely to operate an evaporative cooler: 80°F (26.7°C), 85°F (29.4°C), and 90°F (32.2°C). The lower limit of the range corresponds to the upper limit of the comfort zone for a relative humidity of about 20% (Watt and Brown 1997 [159497], p. 33). The relative humidity of 20% corresponds well to the mean values measured at Site 9 on the Nevada Test Site during the summer months (CRWMS M&O 1999 [102877], p. A-10). Therefore, when the outdoor temperature reaches 80°F (26.7°C) it is possible, but not likely that people would turn on their coolers. Also, they probably would not run them for the whole day because during most of the day the temperature would be lower than 80°F (26.7°C). The upper limit of the range is 10°F higher, which is approximately the width (range) of the temperature comfort zone (Watt and Brown 1997 [159497], p. 33). It is assumed in the biosphere model (BSC 2003 [160699], Section 5) that the indoor concentration of airborne contaminants resulting from operation of a cooler persists throughout the day, even for those days when the cooler is operated for only a portion of the day.

For the current climate, the evaporative cooler use factor was calculated using temperatures measured at Yucca Mountain Meteorological Monitoring Site 9 (Section 4.1.6). Data from the four years preceding and including the survey year (1994 through 1997) were used to calculate the number of days per year that the daily maximum temperature exceeded threshold values (Table 6.3-17). The Excel data are listed in Attachment III, *Site 9 Hourly Temperatures and Daily Max Temperatures.xls*. Based on these results, it is recommended that the evaporative cooler use factor for the current climate be represented by the uniform distribution in the range from 0.32 to 0.46.

Data from a weather station at Spokane, Washington, were used to calculate the evaporative cooler use factor for the future climate. This site is representative of the upper bound (i.e., cooler and wetter) of glacial-transition climate state predicted to occur at Yucca Mountain in the future (USGS 2001 [158378], Table 2). The data were obtained from the National Climatic Data Center (NCDC [n.d.] [161091]). Data from six years (1990–1995) were used to calculate the number of days per year that the daily maximum temperature exceeded threshold values (Table 6.3-18). The Excel data are listed in Attachment III, *Spokane Hourly Temperatures and Daily Max Temperatures.xls*. Based on this information, it is recommended that the evaporative cooler use factor for the glacial transition climate be represented by the uniform distribution in the range from 0.03 to 0.14.

Table 6.3-17. Evaporative Cooler Use Factor for the Current Climate.

	> 80°F (>26.7°C)		> 85°F (>29.4°C)		> 90°F (>32.2°C)	
Year	**N days [a]**	**Use Factor [b]**	**N days [a]**	**Use Factor [b]**	**N days [a]**	**Use Factor [b]**
1994	161	0.44	142	0.39	124	0.34
1995	154	0.42	130	0.36	103	0.28
1996	172	0.47	149	0.41	126	0.34
1997	178	0.49	149	0.41	117	0.32
Average	166	0.46 ± 0.03	143	0.39 ± 0.02	118	0.32 ± 0.03

SOURCE: DTN: MO9905VMMDJM94.000 [150068], MO9905VMMDAJ94.000 [150133], MO9905VMMDJS94.000 [150134], MO9905VMMDOD94.000 [150137], TM000000000001.065 [161051], TM000000000001.068 [161050], TM000000000001.071 [161049], TM000000000001.077 [152925], MO9903VALMM961.000 [150063], MO9903VALMM962.000 [150132], MO9903VALMM963.000 [150130], MO9903VALMM964.000 [150131], TM000000000001.100 [135874], TM000000000001.104 [135876], TM000000000001.107 [135878], MO98METDATA110.000 [135880].

NOTES: [a] Number of days per year that daily maximum temperature exceeded threshold temperature.
[b] Percentage of days per year that daily maximum temperatures exceeded threshold temperature.

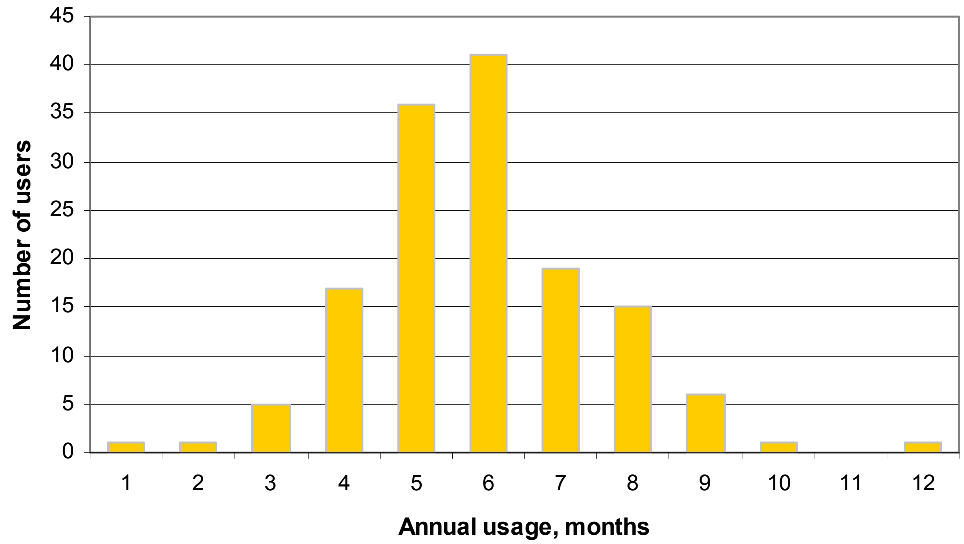
Table 6.3-18. Evaporative Cooler Use Factor for the Glacial Transition Climate.

	> 80°F (>26.7°C)		> 85°F (>29.4°C)		> 90°F (>32.2°C)	
Year	**N days [a]**	**Use Factor [b]**	**N days [a]**	**Use Factor [b]**	**N days [a]**	**Use Factor [b]**
1990	59	0.16	40	0.11	15	0.04
1991	48	0.13	25	0.07	12	0.03
1992	56	0.15	40	0.11	19	0.05
1993	32	0.09	12	0.03	1	0.00
1994	67	0.18	41	0.11	20	0.05
1995	47	0.13	18	0.05	3	0.01
Average	52	0.14 ± 0.03	29	0.08 ± 0.04	12	0.03 ± 0.02

SOURCE: (NCDC [n.d.] [161091]).

NOTES: [a] Number of days per year that daily maximum temperature exceeded threshold temperature.
[b] Percentage of days per year that daily maximum temperatures exceeded threshold temperature.

The distribution developed for the current climate (0.32 to 0.46) is corroborated by the results of the regional survey (DTN: MO0106SPAECL02.016 [160256]; DOE 1997 [100332]). According to that survey, evaporative coolers are used by residents of the Amargosa Valley from 1 to 12 months a year (Figure 6.3-1), with an average of 5.9 months (49% of the year) and a SE of 0.14 months (the figure and summary statistics are from the Excel spreadsheet *Food Consumption Rates Histograms.xls* in Attachment III). Figure 6.3-1 is based on all responses for the Amargosa Valley (195 responses), including people who were not year-round residents of the area or who lived in the area less than 1 year (4 individuals) and people who did not provide a usable response to the question on the number of years residing in the area (4 individuals). The SE was calculated as the ratio of standard deviation and the square root of the number of household equipped with an evaporative cooler.



Source: DTN: MO0106SPAECL02.016 [160256]

Figure 6.3-1. Evaporative Cooler Use in the Amargosa Valley

The average response to the survey question is about 10% higher than the average of the distribution based on daily maximum temperatures, and 3% higher than the maximum of that distribution (Table 6.3-17). It is expected that responses to the survey would result in a higher estimate of cooler use because the survey asked how many months per year an evaporative cooler was used. Coolers would be run for only a portion of the cooler months of early spring and late fall; therefore, an estimate based on days per year of operation should be lower than one based on months per year. Also, some survey respondents may have counted months during which they operated a cooler to ventilate their homes without running the water pump.

6.4 DIETARY CHARACTERISTICS OF THE RECEPTOR

This section describes the development of the parameters related to the dietary characteristics of the RMEI. Distributions of consumption rates for locally produced foods were developed based on the food consumption survey (DTN: MO0010SPANYE00.001 [154976]) and information on daily food intake in the western United States (USDA 2000 [154158]).

Water consumption is defined at 10 CFR 63.312(d) [156605], where it is stated that the RMEI drinks 2 liters of water per day (2 L/d × 365.25 d/yr = 730.5 L/yr).

Another dietary attribute of the RMEI is the inadvertent soil ingestion rate. A rate of soil ingestion consistent with the region and lifestyle of the Amargosa Valley population was developed based on a literature review.

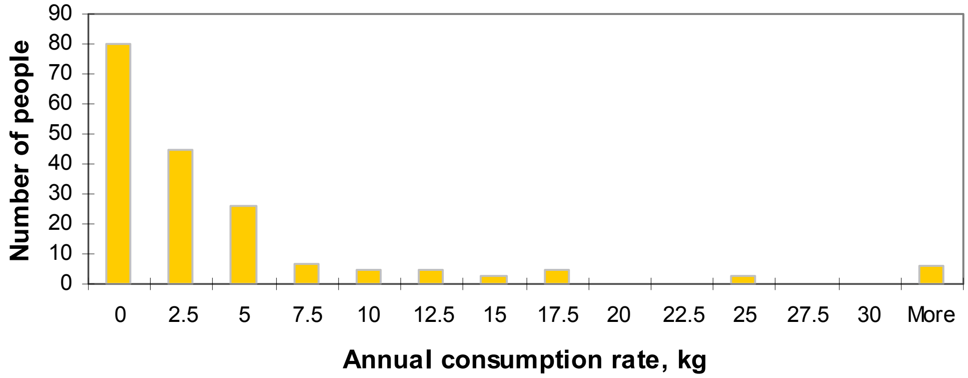
6.4.1 Food Consumption Survey

Attributes of the dietary characteristics for the RMEI were based on the 1997 regional survey conducted in parts of Nye and Clark Counties in the Yucca Mountain region (DOE 1997 [100332]). The objective of the survey was to collect socioeconomic information for biosphere modeling. Dietary and lifestyle data were collected on adults residing within a 50-mile grid centered on Yucca Mountain. It was estimated that nearly 13,000 adults resided in the total study area at the time of the survey, with about 900 of them in the Amargosa Valley (DOE 1997 [100332], p. vi). The survey sample consisted of 1,079 responses, with an Amargosa Valley sample of 195. To meet the requirements of 10 CFR 63.312(b), only information from full-time residents of the Amargosa Valley were used in this analysis.

The food consumption module of the regional survey determined the consumption frequencies of locally produced food. To estimate individual consumption rates, consumption frequencies were combined with the food consumption estimates from the USDA data, concerning daily intakes of food to calculate annual consumption rates of locally produced food. The individual consumption rates of locally produced food were calculated in BSC (2001 [156016]). The results of these calculations (DTN: MO0106SPAECL02.016 [160256]) were used to produce histograms of locally produced food consumption rates for the food types considered in the model (Figures 6.4-1 through 6.4-9). Some food groups used in the food consumption survey were combined as described later (Section 6.4.2). The histograms were produced using the information in the data set DTN: MO0106SPAECL02.016 [160256]. The Excel worksheet *Food Consumption Rates Histograms.xls* containing the data is included in Attachment III.

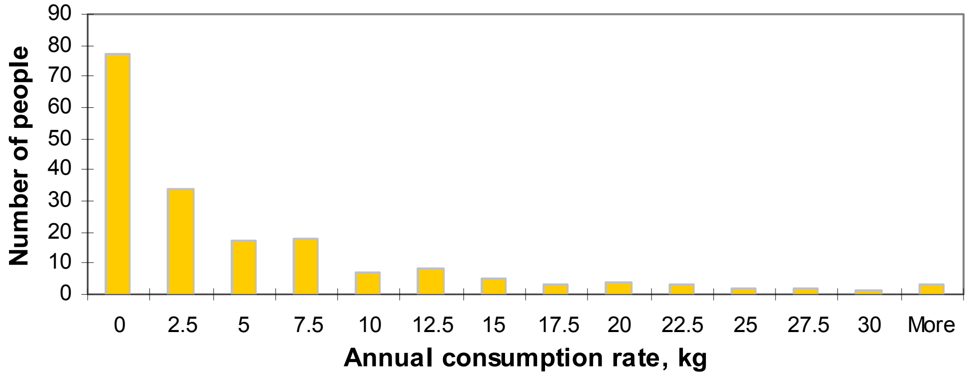
The calculated values of locally produced food consumption rates (DTN: MO0106SPAECL02.016 [160256]) did not include consideration of uncertainty. Therefore they were not used in this analysis and the histograms in Figures 6.4-1 through 6.4-9 are shown here for illustration purposes only. To include uncertainty, the food consumption rates were recalculated from the consumption frequency information and the USDA data, as described in Section 6.4.2. The histograms were produced using all survey results for The Amargosa Valley (195 responses), including individuals who were not year-round residents of the area or lived in the area less than 1 year (4 individuals) and those that did not provide a usable response to question on number of years in the area (4 individuals). These respondents were not included in calculation of the consumption rates, as described in Section 6.4.2, because the consumption rates for the biosphere model concern the annual exposure of adults.

A large number of the surveyed individuals indicated that they consumed little, if any, locally produced food (Figures 6.4-1 through 6.4-9). Only a few individuals consumed a substantial amount of food of any given food type. The first bar in Figures 6.4-1 through 6.4-9 depicts the number of respondents who did not consume a food type, the second bar corresponds to a consumption rate from greater than zero to the value under the second bar, the third bar corresponds to consumption rates from the value under the second bar to the value under the third bar, and so on.



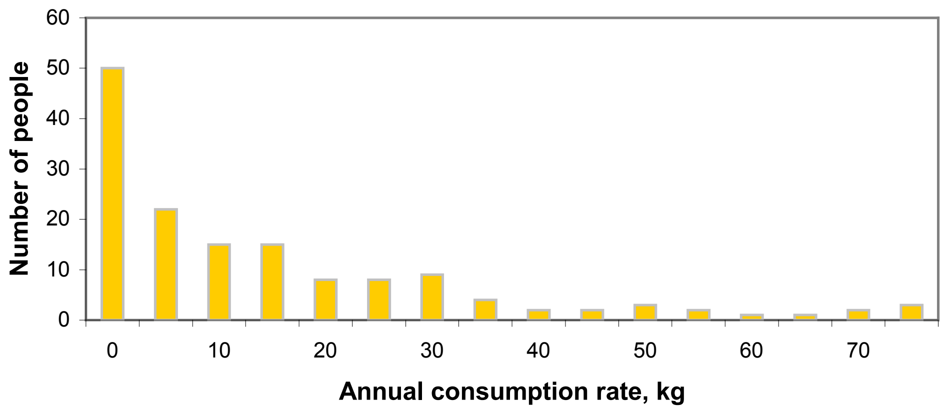
Source: DTN: MO0106SPAECL02.016 [160256]

Figure 6.4-1. Annual Consumption Rates of Locally Produced Leafy Vegetables



Source: DTN: MO0106SPAECL02.016 [160256]

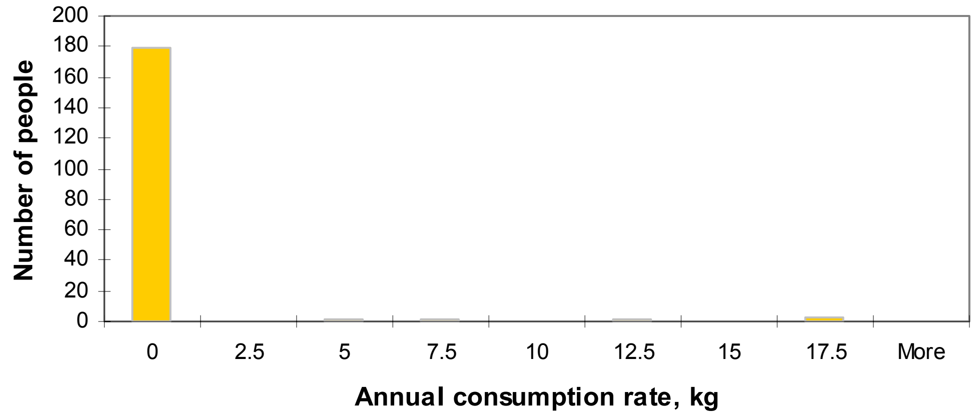
Figure 6.4-2. Annual Consumption Rates of Locally Produced Other Vegetables



Source: DTN: MO0106SPAECL02.016 [160256]

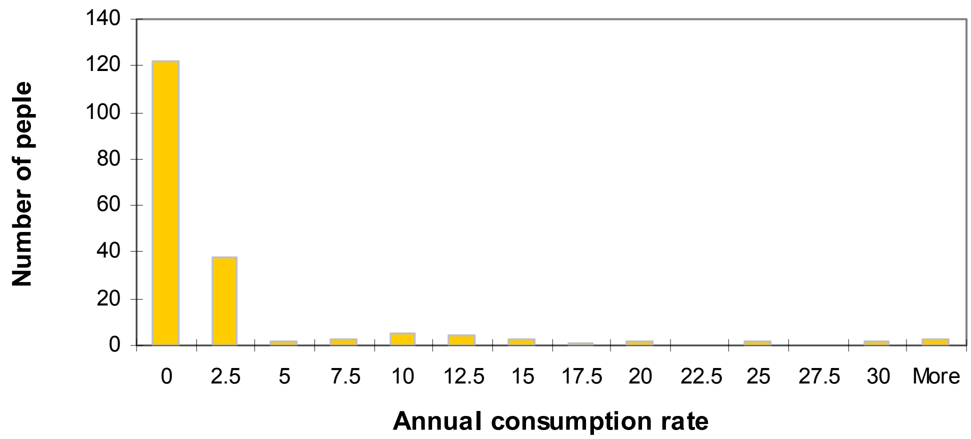
NOTE: Locally produced fruit includes tomatoes.

Figure 6.4-3. Annual Consumption Rates of Locally Produced Fruit



Source: DTN: MO0106SPAECL02.016 [160256]

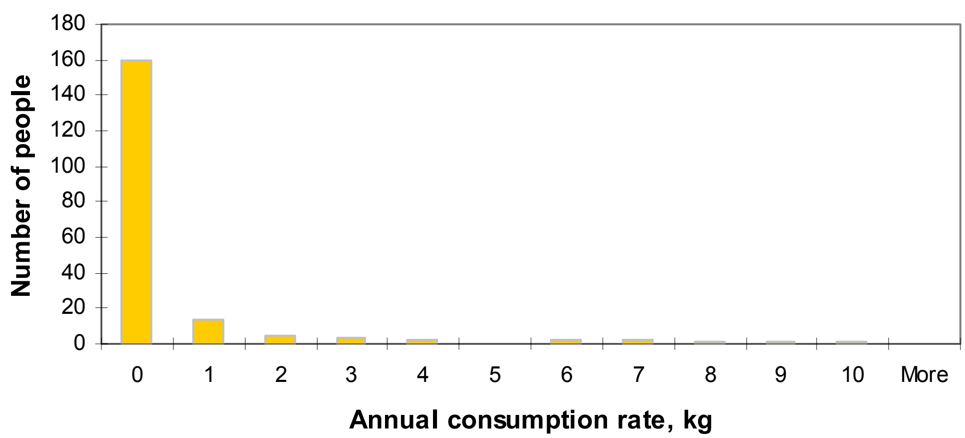
Figure 6.4-4. Annual Consumption Rates of Locally Produced Grain



Source: DTN: MO0106SPAECL02.016 [160256]

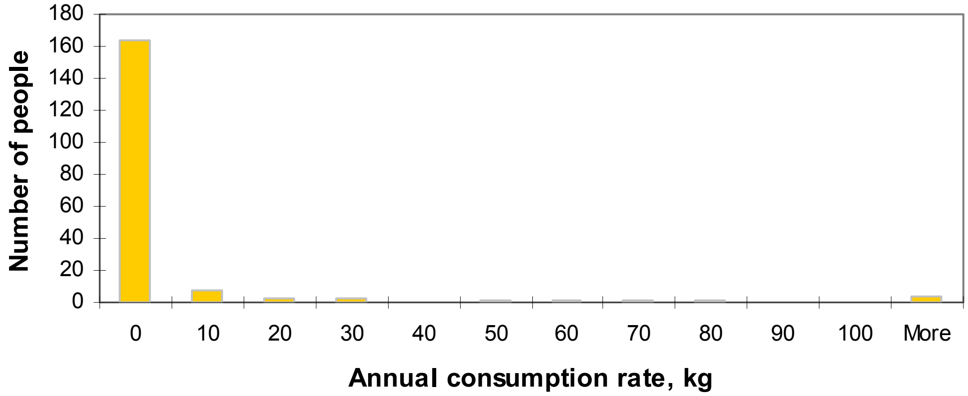
NOTE: Meat includes beef, pork and wild game.

Figure 6.4-5. Annual Consumption Rates of Locally Produced Meat



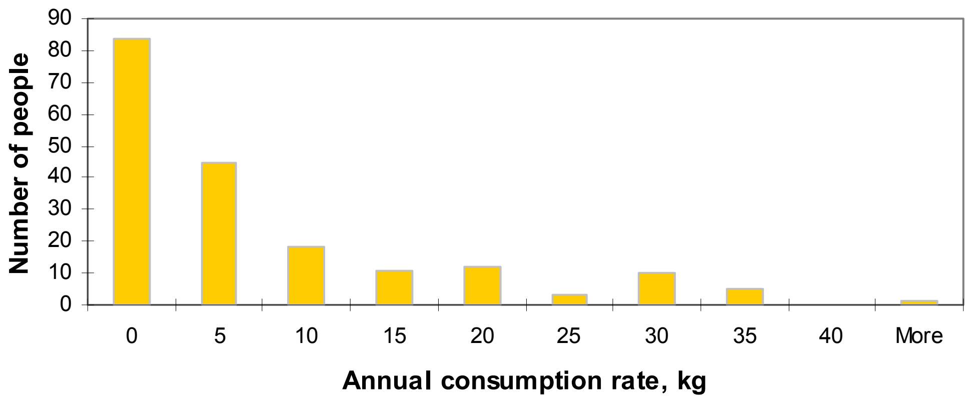
DTN: MO0106SPAECL02.016 [160256]

Figure 6.4-6. Annual Consumption Rates of Locally Produced Poultry



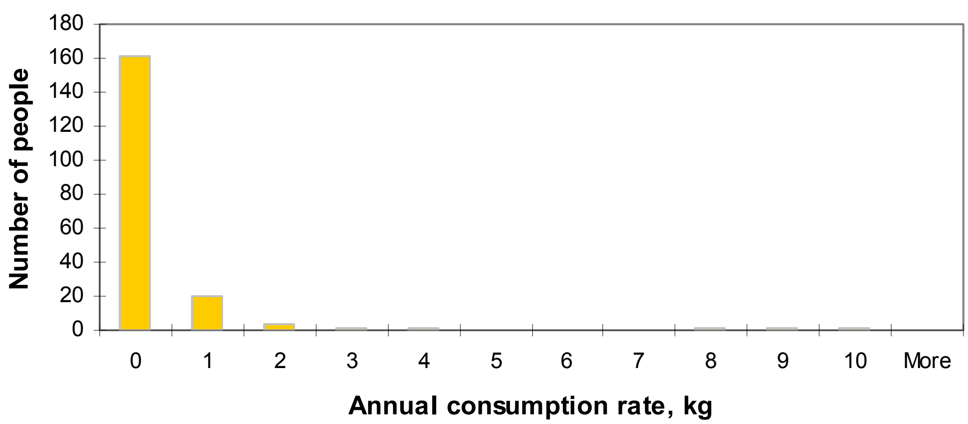
Source: DTN: MO0106SPAECL02.016 [160256]

Figure 6.4-7. Annual Consumption Rates of Locally Produced Milk



Source: DTN: MO0106SPAECL02.016 [160256]

Figure 6.4-8. Annual Consumption Rates of Locally Produced Eggs



Source: DTN: MO0106SPAECL02.016 [160256]

Figure 6.4-9. Annual Consumption Rates of Locally Produced Fish

6.4.2 Calculation of Annual Consumption Rates of Locally Produced Food for the RMEI

To include the consideration of uncertainty in the results of the food consumption survey, the annual consumption rates of locally produced food were recalculated from the frequency information and average daily food intake information. The frequency of consumption of locally produced food for the Amargosa Valley population was obtained from the 1997 survey of Amargosa Valley residents (DTN: MO0010SPANYE00.001 [154976]). The average daily intake was obtained from the USDA 1994-96 Continuing Survey of Food Intakes by Individuals (CSFII) (USDA 2000 [154158]). Table 6.4-1 contains the values of the ADIs, fraction of people consuming, and the respective SE for the food groups included in the 1997 survey (BSC 2001 [156016], p. 10).

The frequency of consumption can be calculated using the individual responses to the regional food consumption survey questions. The following description of the survey questions related to the food consumption is paraphrased from DOE (1997 [100332], p. 30-31). For every food group, a series of four questions was asked. The first question asked if the respondent ate any locally produced food in a food group during the past year. Those who answered "yes" proceeded to the second, third and fourth questions. Those who answered "no" skipped to the next series of questions.

For a respondent who answered "yes" to the first question, the second question was how many months during the last year had some locally produced food in a food group been eaten. The response categories were 1-3 months, 4-6 months, 7-9 months, and 10-12 months. For calculating the food consumption rates, these responses were assigned the following values; 2, 5, 8, and 11 months, respectively (BSC 2001 [156016], p. 16). The third question was how many days per week had locally produced food been eaten (for those months when that locally-produced food had been eaten): less than 1 day per week, 1-2 days per week, 3-4, 5-6, or 7 days per week. The corresponding values used in calculations were 0.5, 1.5, 3.5, 5.5, and 7 days per week, respectively (BSC 2001 [156016], p. 16). The fourth question was how much of the total amount of food consumed was locally produced (for the months when locally-produced food had been eaten): all, most, some, or very little. These responses were assigned the following values: 100%, 75%, 50%, and 25%, respectively (BSC 2001 [156016], p. 17).

Based on the responses to the survey questions and the value of the contingent average daily intake (CADI), annual food consumption rates were calculated as follows:

$$U_{i,j} = MPY_{i,j} \frac{365.25\ d}{12\ mo} DPW_{i,j} \frac{1\ wk}{7\ d} Q_{i,j}\ CADI_i = EDPY_{i,j}\ CADI_i$$

and

$$EDPY_{i,j} = MPY_{i,j} \frac{365.25\ d}{12\ mo} DPW_{i,j} \frac{1\ wk}{7\ d} Q_{i,j} \qquad \text{Eq. 6.4-1}$$

where

$U_{i,j}$ = annual consumption of locally produced food from food group i by individual j (kg/yr)

$MPY_{i,j}$ = number of months per year that individual j consumed locally produced food from group i (mo/yr)

$DPW_{i,j}$ = number of days per week that individual j consumed locally produced food from group i (d/wk)

$Q_{i,j}$ = locally produced fraction of total consumption during the months in which respondent j consumed locally produced food from group i (dimensionless)

$CADI_I$ = contingent average daily intake of food from group i (kg/d)

$EDPY_{i,j}$ = effective number of days per year that individual j consumed locally produced food from group i (d/yr)

The CADI is the quantity that can be calculated from the average daily intake by dividing it by the fraction of people consuming food from a given food group on a day of the survey. The CADI is the average amount of food from each group that is consumed by individuals on the days that they consumed some food from that group, so it applies to the "doers".

Consumption rates presented in this report are based on a 365.25-day year to match the number of days per year used in the biosphere model. This approach is valid because the responses to survey questions concerning consumption of locally produced food do not depend on the number of days per year (see paragraphs above).

The last parameter in Equation 6.4-1, $EDPY_{i,j}$, combines the results of the survey on consumption frequency of locally produced food for a given individual and a given food group. It is numerically equal to the number of days in a year at 100% consumption of locally produced food from a given food group by a given individual.

The average consumption rate of locally produced food is calculated as

$$U_i = \overline{EDPY}_{i,m}\ CADI_{i,m}\ PM + \overline{EDPY}_{i,f}\ CADI_{i,f}\ PF \qquad \text{Eq. 6.4-2}$$

where

U_i = annual average consumption of locally produced food from food group i for Amargosa Valley adults (kg/yr)

$\overline{EDPY}_{i,m}$ = mean effective number of days per year that males from the Amargosa Valley population consumed locally produced food from group i (d/yr)

$CADI_{i,m}$ = contingent average daily intake of food from food group i for males (kg/d)

PM = percent adult males in the Amargosa Valley population

$\overline{EDPY}_{i,f}$ = mean effective number of days per year that females from the Amargosa Valley population consumed locally produced food from group i (d/yr)

$CADI_{i,f}$ = contingent average daily intake of food from food group i for females (kg/d)

PF = percent adult females in the Amargosa Valley population.

The SE in the value of U_i can be evaluated using the general formula for propagating errors (based on Bevington and Robinson 1992 [147076], Section 3.2, Equation 3.14, and examples in Section 3.3) as

$$SEM_{U_i}{}^2 = \left(\frac{\partial U_i}{\partial \overline{EDPY}_{i,m}}\right)^2 \left(SEM_{\overline{EDPY}_{i,m}}\right)^2 + \left(\frac{\partial U_i}{\partial CADI_{i,m}}\right)\left(SEM_{CADI_{i,m}}\right)^2 + + \left(\frac{\partial U_i}{\partial \overline{EDPY}_{i,f}}\right)^2 \left(SEM_{\overline{FDPY}_{i,f}}\right)^2 + \left(\frac{\partial U_i}{\partial CADI_{i,f}}\right)^2 \left(SEM_{CADI_{i,f}}\right)^2 \qquad \text{Eq. 6.4-3}$$

where

$SEM_{\overline{EDPY}_{i,m}}$	=	SE of the mean effective number of days per year that males from the Amargosa Valley population consumed locally produced food from group *i* (d/yr)
$SEM_{CADI_{i,m}}$	=	SE of the mean CADI of food from food group *i* for males (kg/d)
$SEM_{\overline{EDPY}_{i,f}}$	=	SE of the mean effective number of days per year that females from the Amargosa Valley population consumed locally produced food from group *i* (d/yr)
$SEM_{CADI_{i,f}}$	=	SE of the mean CADI of food from food group *i* for females (kg/d).

Using the expression for U_i (Equation 6.4-2), the SE of the mean consumption rate of food from group *i* is calculated as

$$SEM_{U_i}{}^2 = \left(\left(CADI_{i,m}\right)^2 \left(SEM_{\overline{EDPY}_{i,m}}\right)^2 + \left(\overline{EDPY}_{i,m}\right)^2 \left(SEM_{CADI_{i,m}}\right)^2\right)(PM)^2 + \left(\left(CADI_{i,f}\right)^2 \left(SEM_{\overline{EDPY}_{i,f}}\right)^2 + \left(\overline{EDPY}_{i,f}\right)^2 \left(SEM_{CADI_{i,f}}\right)^2\right)(PF)^2 \qquad \text{Eq. 6.4-4}$$

As noted above, the value of CADI is defined as the average amount of food from a given food group that is consumed during a one-day period by all individuals who consumed that food. In other words, the people who did not consume that food are not included in calculation of the CADI. The CADI (BSC 2001 [156016], p. 7) is computed as

$$CADI_i = \frac{ADI_i}{FPC_i} \qquad \text{Eq. 6.4-5}$$

where

$CADI_i$	=	contingent average daily intake of food group *i* (kg/d)
ADI_i	=	average daily intake of food group *i* (kg/d)
FPC_i	=	fraction of people consuming food from food group *i* per day (dimensionless).

The SE of the CADI values can be calculated using the formula for error propagation (based on Bevington and Robinson 1992 [147076], Equation 3.14 in Section 3.2 and examples in Section 3.3) as

$$SEM_{CADI_i}{}^2 = \left(\frac{\partial CADI_i}{\partial ADI_i}\right)^2 \left(SEM_{ADI_i}\right)^2 + \left(\frac{\partial CADI_i}{\partial FPC_i}\right)^2 \left(SEM_{FPC_i}\right)^2 =$$

$$= \left(\frac{1}{FPC_i}\right)^2 \left(SEM_{ADI_i}\right)^2 + \left(-\frac{ADI_i}{(FPC_i)^2}\right)^2 \left(SEM_{FPC_i}\right)^2 =$$

$$= \left(\frac{SEM_{ADI_i}}{FPC_i}\right)^2 + \left(\frac{ADI_i\ SEM_{FPCi}}{(FPC_i)^2}\right)^2$$

$$SEM_{CADI_i} = \sqrt{\left(\frac{SEM_{ADI_i}}{FPC_i}\right)^2 + \left(\frac{ADI_i\ SEM_{FPCi}}{(FPC_i)^2}\right)^2} \qquad \text{Eq. 6.4-6}$$

where

SEM_{CADI_i}	=	SE of the mean CADI for food type *i*
SEM_{ADI_i}	=	SE of the mean average daily intake, *ADI*, for food type *i*
SEM_{FPCi}	=	SE of the mean fraction of people consuming, *FPC*, for food type *i*

The SEs of the CADIs calculated using Equation 6.4-6 are shown in Table 6.4-1.

The effective number of days per year that individual members of the Amargosa Valley population consumed locally produced food from group *i* (d/yr) were calculated from the survey data using equation 6.4-1. The mean values, separately for the males and females, as well as the standard deviations, count, and SEs of the means were calculated in an Excel spreadsheet (Attachment I). The Excel file, *Consumption rates with uncertainties.xls*, is included in Attachment III. The summary of the statistics is provided in Table 6.4-1.

The mean consumption rates of locally produced food for both genders for the survey food groups were then calculated using Equation 6-4.2 and the SE of the means were calculated using equation 6.4-4. These calculations are shown in Attachment I and the results are summarized in Table 6.4-2.

The values of percent population (*PM* and *PF* in Equations 6.4-2 and 6.4-4) were based on the 2000 Census data (Bureau of the Census 2002 [159728], Table P8) rather than the food consumption survey data to correctly represent the proportions of genders for the current population (women were over-represented in the regional survey (DOE 1997 [100332], Section

3.5 and Table 3.5.2)). The 2000 Census data indicated that there were fewer women then men among the population of the Amargosa Valley.

The food types used in the biosphere model are not exactly the same as the food groups used in the regional survey. For the biosphere model some of the regional survey food groups were combined as shown below.

Regional Survey Food Group		Biosphere Model Food Type
Leafy Vegetables	→	Leafy Vegetables
Other vegetables	→	Other vegetables
Fruit Tomatoes	→	Fruit
Grain	→	Grain
Beef Pork Wild Game	→	Meat
Poultry	→	Poultry
Milk	→	Milk
Eggs	→	Eggs
Fish	→	Fish

The mean consumption rates for meat and fruit, which are composed of more than one food group used in the regional survey, were calculated by adding the mean consumption rates for the regional survey food groups. The calculation of the SEs of the means was performed by taking the square root of the sum of squares of SEs of the consumption rates for the regional survey (Attachment I). The results are also shown in Table 6.4-2.

Table 6.4-1. Annual Daily Intake and Fraction of People Consuming for Respondents in the Western Region and the Calculated Contingent Annual Daily Consumption by Food Type

1997 Food Consumption Survey Food Group	94-96 CSFII Food Group [a]	Gender	Average Daily Intake (g) [b]		Fraction of People Consuming (dimensionless) [b]		Contingent Average Daily Intake (g) [c]	
			AM	SE	AM	SE	AM	SE
Leafy Vegetables	Dark-green vegetables	M	13	3	0.103	0.015	126.2	34.4
		F	16	3	0.133	0.014	120.3	25.9
Other vegetables	White potatoes	M	66	6	0.417	0.021	158.3	16.4
		F	43	3	0.350	0.016	122.9	10.2
Fruit	Total fruits	M	194	12	0.535	0.022	362.6	26.9
		F	181	15	0.603	0.025	300.2	27.8
Tomatoes	Tomatoes	M	43	2	0.447	0.010	96.2	5.0
		F	27	2	0.398	0.022	67.8	6.3
Grain	Total grain products	M	382	18	0.973	0.007	392.6	18.7
		F	266	12	0.968	0.005	274.8	12.5
Beef	Beef	M	37	3	0.258	0.024	143.4	17.7
		F	17	2	0.194	0.014	87.6	12.1
Pork	Pork	M	12	2	0.169	0.012	71.0	12.9
		F	6	1	0.132	0.014	45.5	9.0
Wild Game	Lamb, Veal, Game	M	2	1	0.012	0.007	166.7	128.0
		F	1	1	0.010	0.004	100.0	107.7
Poultry	Total poultry	M	29	3	0.215	0.012	134.9	15.9
		F	17	2	0.207	0.018	82.1	12.0
Milk	Total fluid milk	M	193	9	0.496	0.020	389.1	24.0
		F	155	10	0.513	0.025	302.1	24.4
Eggs	Eggs	M	29	3	0.239	0.019	121.3	15.8
		F	18	2	0.189	0.012	95.2	12.2
Fish	Fish and shellfish	M	12	2	0.093	0.009	129.0	24.9
		F	9	2	0.078	0.012	115.4	31.2

NOTES: AM = arithmetic mean.

[a] The food groups were selected such that the resulting CADI is the most conservative (BSC 2001 [156016], p. 8-10).

[b] USDA 2000 [154158]

[c] Calculated using equations 6.4-5 and 6.4-6 in spreadsheet “Consumption rates” of the Excel file “Consumption rates with uncertainties”, as explained in Attachment I.

Table 6.4-2. Effective Number of Days for Consumption of Locally Produced Food and Annual Consumption Rates by Survey Food Group and by Biosphere Model Food Type.

1997 Food Consumption Survey Food Group	Gender	Effective Number of Days per Year When Locally Produced Food is Consumed (d/yr) [a]					Annual Consumption Rate (kg/yr)				Biosphere Model Food Types
							Survey Food Groups		Biosphere Model Food Types		
		AM	ASD	Count	SE	% Popul. [b]	AM [c]	SE [d]	AM	SE	
Leafy vegetables	M	30.70	60.15	70	7.19	0.522	3.78	0.88	3.78	0.88	Leafy vegetables
	F	30.53	60.36	108	5.81	0.478					
Other vegetables	M	30.76	49.61	70	5.93	0.522	4.73	0.67	4.73	0.67	Other vegetables
	F	37.22	58.67	107	5.67	0.478					
Fruit	M	22.16	38.03	70	4.55	0.522	9.35	1.28	12.68 [e]	1.36 [f]	Fruit
	F	35.91	55.12	111	5.23	0.478					
Tomatoes	M	33.25	47.35	53	6.50	0.522	3.33	0.48			
	F	51.17	89.31	87	9.58	0.478					
Grain	M	0.00	0.00	71	0.00	0.522	0.23	0.11	0.23	0.11	Grain
	F	1.76	8.85	106	0.86	0.478					
Beef	M	19.34	61.11	71	7.25	0.522	2.18	0.62	2.85 [g]	0.65 [f]	Meat
	F	17.59	54.34	109	5.20	0.478					
Pork	M	7.63	31.11	71	3.69	0.522	0.53	0.17			
	F	11.59	37.30	112	3.52	0.478					
Wild game	M	0.72	3.33	71	0.40	0.522	0.13	0.10			
	F	1.50	7.76	112	0.73	0.478					
Poultry	M	4.31	13.89	70	1.66	0.522	0.42	0.13	0.42	0.13	Poultry
	F	2.90	11.28	112	1.07	0.478					
Milk	M	13.03	59.93	69	7.21	0.522	4.66	1.68	4.66	1.68	Milk
	F	13.97	56.27	108	5.41	0.478					
Eggs	M	34.82	69.48	70	8.30	0.522	5.30	0.83	5.30	0.83	Eggs
	F	67.86	94.66	111	8.98	0.478					
Fish	M	1.72	8.87	70	1.06	0.522	0.23	0.10	0.23	0.10	Fish
	F	2.13	9.81	112	0.93	0.478					

NOTES: AM = arithmetic mean, ASD = arithmetic standard deviation.

[a] Calculated in Excel spreadsheet from the consumption frequency data (DTN: MO0010SPANYE00.001 [154976]) as described in Attachment I.

[b] Calculated based on Bureau of the Census (2002 [159728], Table P8). Concerns adult population, i.e., more than 17 year old.

[c] Calculated using equation 6.4-2.

[d] Calculated using equation 6.4-4.

[e] Calculated as a sum of consumption rates for fruit and tomatoes.

[f] Calculated by taking the square root of the sum of squares of the SEs of the consumption rates for the regional survey food groups.

[g] Calculated as a sum of consumption rates for beef, pork, and game. The combined value was calculated in the spreadsheet. Therefore it differs by 0.01 kg/yr from the sum of components presented in the table.

The analysis provided above uses data generated from local and national surveys and develops the expected (i.e., mean) value of annual consumption of each food type for the Amargosa Valley population. Being based upon sampling processes, the results are subject to statistical errors that have been quantified in terms of the SE of the value developed (i.e., the expected standard deviation of the estimated mean).

The biosphere model can accept stochastic input to propagate the effects of parametric variability and uncertainty (BSC 2003 [160699], Section 6), and the question arises as to what approach to use to estimate the variability of each parameter around the calculated mean value. One approach would be to use the Student-*t* test for confidence testing (Bulmer 1979 [111961], p. 148) and establish a predetermined confidence limit (such as the 95%) into which the true mean should fall. It could then be stated that, to the predetermined confidence level, the true mean lies over this range with uniform probability. However, for several parameters where the SE has a value similar to the calculated mean, this approach would lead to a sampled value corresponding to negative food consumption rates. If this condition were to be remedied by simple truncation at zero consumption, there would be a systematic bias in the mean value of the sampled parameter.

A more realistic approach can be developed. The calculation of the mean value of a given consumption parameter involves taking the product of several factors, each of which is subject to uncertainty (Equations 6.4-1 and 6.4-2). By considering the logarithm of the parameter, the mathematical operation of taking the product of a number of factors is transformed to taking the sum of the logarithms of each of the factors. Based on the central limit theorem (Bulmer 1979 [111961], p. 115), the distribution of the logarithm of that parameter will be approximately normal. Thus, a reasonable approximating distribution for the actual parameter is a lognormal distribution. A lognormal distribution possesses the beneficial attribute that it is limited to positive parameter values. The use of this distribution eliminates the artificial condition of negative food consumption as discussed above or as would arise by using the normal distribution.

In the analysis to generate the consumption rates, the available data are only sufficient to calculate the first and second moments (the mean and the standard deviation). Any distribution used to approximate the variability of the derived parameters should only require the definition of two parameters to uniquely specify the proposed distribution. The lognormal distribution meets this requirement.

6.4.3 Inadvertent Soil Ingestion

Soil contains the largest inventory of radioactivity of all components of the biosphere system for both exposure scenarios. For the volcanic ash scenario, this is because the soil or the mixture of soil and ash is the source of contamination, and for the groundwater scenario, the soil receives the majority of the contamination from irrigation water. Direct intake of soil was included in the biosphere model. Contamination of surface soil occurs during crop irrigation with contaminated water or during deposition of contaminated volcanic ash on soil surface. For the groundwater exposure scenario, it is assumed that irrigation continues sufficiently long for the buildup of radionuclides and their decay products in soil to occur and for radionuclide concentrations to reach equilibrium (BSC 2003 [160699], Section 5) .

Ingestion of soil by humans can be divided into two distinct phenomena: inadvertent and deliberate (geophagia). Deliberate soil ingestion is frequently referred to as soil pica (pica being defined as an eating disorder manifested by a craving to ingest any material unsuitable for food); thus geophagia is a special case of pica. Inadvertent ingestion of soil may be a result of swallowing dirt or dust accompanying mouth breathing, via food items contaminated with soil, as well as from mouthing of dirty hands or other contaminated non-food items, such as cigarettes (Simon 1998 [160098], p. 648). Increased soil ingestion may be related to the living conditions or professions that bring people into close and continual contact with the soil (Simon 1998 [160098], p. 647). Deliberate soil ingestion is considered to be relatively uncommon (EPA 1997 [103038], p. 4-1).

It is assumed that no adults in the Amargosa Valley are geophagic (Assumption 5.2) because geophagia is usually confined to infants and children (EPA 1997 [103038], Section 4.5). The RMEI is defined as an adult, so the soil ingestion rate characteristic of adults is recommended for the biosphere model.

Soil ingestion rates for the biosphere model were developed based on inadvertent average daily intake of soil reported in the literature. The studies of soil ingestion among adults are limited in number compared with studies of pica in children (EPA 1997 [103038], p. 4-1), and only a few studies involving the direct measurements of adult soil ingestion rates have been conducted. In most publications on the subject of inadvertent soil ingestion by adults, the ingestion rates are estimated partly based on existing measurements and partly on assumptions. Soil ingestion by humans was the a subject of a comprehensive review by Simon (1998 [160098], p. 647-672), which included applications of soil ingestion rate to risk assessment of radioactively contaminated soil. That review includes an evaluation of existing data and their sources as well as recommendations regarding soil ingestion values for different environments, populations, and exposure scenarios.

A summary of the information on inadvertent soil ingestion rates for adults is given in Table 6.4-3, which lists the literature sources and the associated values, ranges, and distributions, where applicable.

The measured and assessed values of inadvertent soil ingestion rates are in the range of less than 1 mg/d for clean indoor environments to several hundred mg/d for dusty outdoor environments (Table 6.4-3). Most of the dose and risk assessment models use 100 mg/d as the default value for the rate of inadvertent soil ingestion (Table 6.4-3). The value of 100 mg/d is also recommended by the EPA for residential and agricultural scenarios (EPA 1997 [103038], p. 4-21). Although the most recent measurements indicate that the soil ingestion rates are about an order of magnitude lower than this value (Stanek et al. 1997 [160251], p. 249), consideration was given to site-specific conditions. The nature of the Amargosa Valley environment, especially the frequent wind, sparse vegetation, and arid climate, suggests that the average value of inadvertent soil ingestion rate of 100 mg/d recommended by the EPA for agricultural scenarios is appropriate for the use in the biosphere model.

Table 6.4-3. Inadvertent Soil Ingestion Rates Reported in the Literature

Reference	Soil Ingestion Rate	Comments
Direct Measurements		
Calabrese et al. 1990 as cited in EPA (1997 [103038], p. 4-21) and in Simon (1998 [160098], p. 652)	30-100 mg/d approximately 50 mg/d	Based on soil trace element measurements in 6 adults; uncertainties due to small sample size and short duration of the study
Stanek et al. 1997 [160251], p. 249	10 mg/d average; SD = 94 mg/d; 95% value 331 mg/d	Based on the soil trace element measurements for 10 adults; lower level of soil ingestion in adults than estimated previously
Assessments, Estimates, and Literature Reviews		
Calabrese 1987 as cited in EPA (1997 [103038], p. 4-17)	1 to 100 mg/d	Suggested values are conjectural and based on fractional estimates of earlier Center for Disease Control estimates.
Finley and Paustenbach 1994 as cited in Simon 1998 [160098], p. 653	0.1 to 50 mg/d for people aged 13-30 yr	Theoretical assessment calculations for exposure to dioxin contamination
Hawley 1985 as cited in EPA (1997 [103038], p. 4-17) and in Simon (1998 [160098], p. 652)	480 mg/d for adults engaged in outdoor activities 0.56 mg/d for ingesting house dust during typical living space activities 110 mg/d for ingestion of house dust while working in attics 60.5 mg/d estimated annual average soil intake rate	Estimated values based on assumptions about soil and dust levels on hands and mouthing behavior.
Kimbrough et al. 1984 as cited in Simon 1998 [160098], p. 652	100 mg/d for people aged > 5y	Theoretical assessment calculations for exposure to dioxin contamination
Martin and Bloom 1975 as cited in Simon 1998 [160098], p. 652	8-11 mg/d	Theoretical assessment calculations for desert environment
Sheppard 1995 as cited in Simon 1998 [160098], p. 654	20 mg/d for adult gardener 0.4 mg/d for adult indoors	Based on literature review
Recommendations		
ATSDR 1992 as cited in Simon 1998 [160098], p. 653	50 mg/d	
EPA 1997 [103038], p. 4-21	50 mg/d for industrial settings; a reasonable central estimate of adult soil ingestion and the recommended generic value for soil ingestion 100 mg/d for residential and agricultural scenarios	
Various dose/risk assessment models as described in Simon 1998 [160098], p. 664	100 mg/d	The default value recommended for dose assessment models, such as GENII, and RESRAD
Simon 1998 [160098], p. 663	Lognormal distribution GM from 50 to 200 mg/d depending on the environment GSD = 3.2	Recommended distribution are for occupations on sparsely to heavily vegetated pasture land and for rural lifestyles on sparsely to heavily vegetated land.

The uncertainty distributions recommended by Simon (1998 [160098], p. 663) for the inadvertent soil ingestion rate are lognormal with the geometric standard deviation (GSD) of 3.2. Because the RMEI represents the average adult in the Amargosa Valley population, the uncertainty distribution for the rate of inadvertent soil ingestion should be associated with the uncertainty of the mean rather than with the population variability. The GMs of the uncertainty distributions recommended by Simon (1998 [160098], p. 663) for the inadvertent soil ingestion rate for various agricultural scenarios and rural lifestyles range from 50 to 200 mg/d. Therefore, it is recommended that the inadvertent soil ingestion for the RMEI be represented by a piece-wise cumulative distribution with the following characteristics: (50 mg/d, 0%), (100 mg/d, 50%), and (200 mg/d, 100%). The mean value is 112.5 mg/d, which agrees well with the value of 100 mg/d recommended by the EPA and used in other assessment models (Table 6.4-3). The mean value of the distribution can be obtained by calculating the probability density function *f(x)* for the soil ingestion rate. It consists of the two uniform sections with the values of 0.5/(100 mg/d - 50 mg/d) = 0.01 d/mg for the range from 50 to 100 mg/d and 0.5/(200 mg/d - 100 mg/d) = 0.005 d/mg for the range from 100 to 200 mg/d. The mean value is calculated as

$$\int_{50}^{100} 0.01\,x\,dx + \int_{100}^{200} 0.005\,x\,dx = 0.01\left[0.5x^2\right]_{50}^{100} + 0.005\left[0.5x^2\right]_{100}^{200} =$$
$$= 0.01 \times 0.5[10000 - 2500] + 0.005 \times 0.5[40000 - 10000] = 112.5$$

Because there are few direct measurements of inadvertent soil ingestion by adults, EPA (1997 [103038], p. 4-21) indicates that the recommended values of inadvertent soil ingestion are uncertain. Therefore it is recommended that the same distribution of soil ingestion rate be used for all population groups, all environments, both exposure scenarios, and for the current and future climates. The recommended uncertainty distribution sufficiently represent the range of possible values.

6.5 DOSIMETRY CONSIDERATIONS

The function of the biosphere model is to calculate doses resulting from the radiation exposure of the receptor. This is accomplished by evaluating radionuclide intake or external exposure of the receptor, which are subsequently converted to radiation doses. The conversion is based on radionuclide-specific DCFs for internal exposure (inhalation or ingestion) and dose coefficients for external exposure. This section develops or recommends the values of conversion factors for the use in the biosphere model.

6.5.1 Radionuclides and Elements Included in the Analysis

Twenty-eight radionuclides were identified as important for the TSPA assessment (BSC 2002 [160059], p. 39). The list includes radionuclides that are potentially significant dose contributors during the compliance period (up to 10,000 years) and the period of up to 1,000,000 years for both exposure scenarios.

Some of the radionuclides of interest for TSPA are accompanied in the source (e.g., groundwater or volcanic ash) by long-lived decay products, which are not individually tracked in the TSPA model. The biosphere model accounts for exposures to these radionuclides. In the biosphere model, the decay products of primary radionuclides with half-lives less than 180 days are assumed to be in secular equilibrium with the parent radionuclides, and their contributions to the BDCFs (doses) are included in the BDCF (doses) for the primary radionuclide (BSC 2003 [160699], Section 6.3.5). The decay products of primary radionuclides with half-lives longer than 180 days are treated like primary radionuclides (BSC 2003 [160699], Section 6.3.5). Three such radionuclides, ^{228}Th, ^{228}Ra, and ^{235}U were added to the list, resulting in a set of thirty-one primary radionuclides (Table 6.5-1). This table also lists the short-lived (half-life less than 180 days) decay products as well as the half-lives and branching fractions for the primary radionuclides and their decay products. Detailed discussion of the treatment of decay products in the biosphere model is presented in BSC (2003 [160699], Sections 6.3.5 and 6.4.1.2).

6.5.2 Dosimetric Approaches

To demonstrate compliance with licensing regulations (10 CFR 63.311 [156605]), the results of performance assessment are compared with the individual protection standard expressed in terms of the annual dose. The annual dose in 10 CFR 63.311 [156605] is equivalent to the total effective dose equivalent (TEDE) from annual exposure (66 FR 55732 [156671], pp. 55734 to 55735). The TEDE is the quantity typically used to specify dose limits for occupational exposure and is defined in 10 CFR 20.1003 [104787] as the sum of deep dose equivalent resulting from exposure to external radiation and the committed effective dose equivalent (CEDE) resulting from internal contamination. For assessing doses to the RMEI, the TEDE is the sum of the effective dose equivalent (EDE) for external exposures and the CEDE for internal exposures (10 CFR 63.2 [156605]). The use of the EDE in place of the deep dose equivalent in dose assessment is consistent with NRC guidance (NRC 2003 [163018]). The TEDE from annual exposure used in 10 CFR Part 63 [156605] is also equivalent to the annual CEDE used by EPA in the individual protection standard (40 CFR 197.20 [155238]). The annual CEDE as defined by EPA is the sum of the CEDE from internal doses resulting from 1 yr of intake of radioactive materials plus the EDE from external radiation exposure during the year.

CEDE is defined by the NRC as the “sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to those organs or tissues” (10 CFR 20.1003 [104787]). In determining annual TEDE for assessing doses to members of the public (10 CFR Part 63 [156605]), the external dose component (EDE) also involves summing the products of organ doses and weighting factors (66 FR 55732 [156671], pp. 55734 to 55735).

Table 6.5-1. Primary Radionuclides and Their Decay Products Included in the Biosphere Model

Primary Radionuclide	Short-lived Decay Product	Branching Fraction, % [a]	Half-life [a]
Carbon-14 (^{14}C)		100	5730 yr
Chlorine-36 (^{36}Cl)		100	3.01E+05 yr
Selenium-79 (^{79}Se)		100	6.50E+04 yr
Strontium-90 (^{90}Sr)		100	29.12 yr
	Yttrium-90 (^{90}Y)	100	64.0 hr
Technetium-99 (^{99}Tc)		100	2.13E+05 yr
Tin-126 (^{126}Sn)		100	1.0E+05 yr
	Antimony-126m (^{126m}Sb)	100	19.0 min
	Antimony-126 (^{126}Sb)	14	12.4 d
Iodine-129 (^{129}I)		100	1.57E+07 yr
Cesium-135 (^{135}Cs)		100	2.3E+06 yr
Cesium-137 (^{137}Cs)		100	30.0 yr
	Barium-137m (^{137m}Ba)	94.60	2.552 min
Thorium Series (4n)			
Plutonium-240 (^{240}Pu)		100	6.537E+03 yr
Uranium-236 (^{236}U)		100	2.3415E+07 yr
Thorium-232 (^{232}Th)		100	1.405E+10 yr
Radium-228 (^{228}Ra)		100	5.75E+00 yr
	Actinium-228 (^{228}Ac)	100	6.13 hr
Uranium-232 (^{232}U)		100	72 yr
Thorium-228 (^{228}Th)		100	1.9131 yr
	Radium-224 (^{224}Ra)	100	3.66 d
	Radon-220 (^{220}Rn)	100	55.6 s
	Polonium-216 (^{216}Po)	100	0.15 s
	Lead-212 (^{212}Pb)	100	10.64 hr
	Bismuth-212 (^{212}Bi)	100	60.55 min
	Polonium-212 (^{212}Po)	64.07	0.305 μs
	Thallium-208 (^{208}Tl)	35.93	3.07 min
Neptunium Series (4n+1)			
Americium-241 (^{241}Am)		100	432.2 yr
Neptunium-237 (^{237}Np)		100	2.14E+06 yr
	Protactinium-233 (^{233}Pa)	100	27.0 d
Uranium-233 (^{233}U)		100	1.585E+05 yr
Thorium-229 (^{229}Th)		100	7340 yr
	Radium-225 (^{225}Ra)	100	14.8 d
	Actinium-225 (^{225}Ac)	100	10.0 d
	Francium-221 (^{221}Fr)	100	4.8 min
	Astatine-217 (^{217}At)	100	32.3 ms
	Bismuth-213 (^{213}Bi)	100	45.65 min
	Polonium-213 (^{213}Po)	97.84	4.2 μs
	Thallium-209 (^{209}Tl)	2.16	2.20 min
	Lead-209 (^{209}Pb)	–	3.253 hr

Table 6.5-1. Primary Radionuclides and Their Decay Products Included in the Biosphere Model (continued)

Primary Radionuclide	Short-lived Decay Product	Branching Fraction, % [a]	Half-life [a]
Uranium Series (4n + 2)			
Plutonium-242 (^{242}Pu)		100	3.763E+05 yr
Uranium-238 (^{238}U)		100	4.468E+09 yr
	Thorium-234 (^{234}Th)	100	24.10 d
	Protactinium-234m (^{234m}Pa)	99.80	1.17 min
	Protactinium-234 (^{234}Pa)	0.33	6.70 hr
Plutonium-238 (^{238}Pu)		100	87.74E+01 yr
Uranium-234 (^{234}U)		100	2.445E+05 yr
Thorium-230 (^{230}Th)		100	7.7E+04 yr
Radium-226 (^{226}Ra)		100	1600 yr
	Radon-222 (^{222}Rn)	100	3.8235 d
	Polonium-218 (^{218}Po)	100	3.05 min
	Lead-214 (^{214}Pb)	99.98	26.8 min
	Astatine-218 (^{218}At)	0.02	2 s
	Bismuth-214 (^{214}Bi)	100	19.9 min
	Polonium-214 (^{214}Po)	99.98	164.3 μs
	Thallium-210 (^{210}Tl)	0.02	1.3 min [b]
Lead-210 (^{210}Pb)		100	22.3 yr
	Bismuth-210 (^{210}Bi)	100	5.012 d
	Polonium-210 (^{210}Po)	100	138.38 d
Actinium Series (4n + 3)			
Americium-243 (^{243}Am)		100	7380 yr
	Neptunium-239 (^{239}Np)	100	2.355 d
Plutonium-239 (^{239}Pu)		100	2.4065E+04 yr
Uranium-235 (^{235}U)		100	703.8E6 yr
	Thorium-231 (^{231}Th)	100	25.52 hr
Protactinium-231 (^{231}Pa)		100	3.276E+04 yr
Actinium-227 (^{227}Ac)		100	21.773 yr
	Thorium-227 (^{227}Th)	98.62	18.718 d
	Francium-223 (^{223}Fr)	1.38	21.8 min
	Radium-223 (^{223}Ra)	100	11.434 d
	Radon-219 (^{219}Rn)	100	3.96 s
	Polonium-215 (^{215}Po)	100	1.78 ms
	Lead-211 (^{211}Pb)	100	36.1 min
	Bismuth-211 (^{211}Bi)	100	2.14 min
	Thallium-207 (^{207}Tl)	99.72	4.77 min
	Polonium-211 (^{211}Po)	0.28	0.516 s

SOURCE:

[a] Eckerman and Ryman 1993 [107684], Table A.1

[b] Lide and Frederikse 1997 [103178], p. 11-125

NOTE: Short-lived decay products of primary radionuclides are assumed to be in secular equilibrium with their parents.

Calculating CEDE and EDE involves using exposure-to-dose conversion factors, more commonly referred to as DCFs or dose coefficients. The exposure-to-dose conversion factor is one of the fundamental representations of a dosimetric model used in assessing potential radiation dose. It allows an intake of, or exposure to, a radionuclide to be converted to radiation dose. The current approach uses dosimetric models based on the concepts recommended in ICRP Publication 26 (ICRP 1977 [101075]) and the dosimetric methods outlined in ICRP Publication 30 (ICRP 1979 [110386]; ICRP 1980 [110351]; ICRP 1981 [110352]). This is consistent with the individual protection standard defined in terms of TEDE and with the NRC guidance on performance assessment methodology (NRC 2000 [157704], Section 3.3.7.1.2). The ICRP-26 and ICRP-30 concepts and methods were used by the EPA to calculate the exposure-to-dose conversion factors for inhalation and ingestion presented in FGR 11 (Eckerman et al. 1988 [101069]) and also dose coefficients for external exposure in FGR 12 (Eckerman and Ryman 1993 [107684]). Although the DCFs and dose coefficients may have considerable uncertainty due to variability in human physiological characteristics, in this analysis they are taken as fixed values, as given in FGR 11 and FGR 12. This approach is recommended by the NRC (2000 [157704], Sections 3.3.7.3.1 and 3.3.7.3.2) for performance assessments.

After the incorporation of ICRP-26 and ICRP-30 methodology into various U.S. regulations, the ICRP introduced new recommendations and issued a new set of exposure-to-dose conversion factors in ICRP Publication 72 (ICRP 1996 [152446]). This set is based on updated biokinetic data and models, and the revised method for computing radiation doses presented in ICRP Publication 60 (ICRP 1991 [101836]). ICRP Publication 60 introduced a new dosimetric quantity, the effective dose, which considers an expanded list of tissues and organs, updated biokinetic data and models, and revised tissue and organ weighting factors. To date, the revised ICRP dosimetric methods and the new exposure-to-dose conversion factors have not been incorporated into U.S. regulations. Because the repository licensing rule uses the concept of TEDE for dose limits, the conversion factors must also be expressed in terms of CEDE and EDE, which are based on the ICRP-30 dosimetric methods. Therefore, the updated conversion factors were not used.

6.5.3 Dose Coefficients for Internal and External Exposure

The primary sources of DCFs for internal and external exposure are FGR 11 (Eckerman et al. 1988 [101069]) and FGR 12 (Eckerman and Ryman 1993 [107684]).

6.5.3.1 Dose Conversion Factors for Inhalation and Ingestion

The DCFs for radionuclide intake by inhalation and ingestion used in the biosphere model are based on the values from the FGR 11 (Eckerman et al. 1988 [101069]). The DCFs for inhalation are for particles with activity median aerodynamic diameter (AMAD) of 1 μm. For many radionuclides, there is only one DCF value for inhalation and one for ingestion. For some radionuclides, FGR 11 gives more than one value of DCF corresponding to different chemical compounds. Different DCFs arise from different fractional uptakes of a radionuclide from the small intestine to the blood and different lung clearance classes (ICRP 1979 [110386], p. 24 and 30 to 31) for various chemical forms of the radionuclide. DCFs for radionuclide intake by inhalation and ingestion were selected such that they correspond to the most conservative conditions for radionuclides under consideration. For most of the radionuclides considered in the biosphere model, if a radionuclide has more than one DCF, the higher DCF is for more soluble compounds. One exception is uranium, for which inhalation DCFs are the highest for the lung clearance class Y (long retention, on the order of years, in the pulmonary region of the lung) and relatively low uptake to blood. In this case, the highest DCF for inhalation and ingestion correspond to different chemical forms of a radionuclide. Despite this inconsistency, selecting the highest DCF value for a radionuclide ensures that the doses from this radionuclide will not be underestimated regardless of the chemical form of the radionuclide in the environment. The NRC recommends (NRC 2000 [157704], Section 3.3.7.3.1) using the most conservative internal DCFs for TEDE calculations for radionuclides that have multiple DCFs based on chemical form, unless a particular chemical form can be justified.

For ^{90}Sr, it is customary to not select the highest DCF for inhalation. The most conservative DCF value for inhalation of strontium is for $SrTiO_3$, which is rare and is considered to be unattainable during transport through environmental media (Rittmann 1993 [107744], p. 6). Therefore, the value for other, more common chemical forms of strontium are used for inhalation and ingestion. Table 6.5-2 contains a summary of the DCFs for inhalation and ingestion that are recommended for use in the biosphere model.

Table 6.5-2. Dose Conversion Factors for Inhalation and Ingestion of Radionuclides of Interest

Primary Radionuclide	Short-lived Decay Product	Dose Conversion Factors (Sv/Bq)	
		Inhalation	Ingestion
Carbon-14 (^{14}C) (as CO_2)		6.36E-12	5.64E-10
Chlorine-36 (^{36}Cl)		5.93E-09	8.18E-10
Selenium-79 (^{79}Se)		2.66E-09	2.35E-09
Strontium-90 (^{90}Sr)		6.47E-08 [a]	3.85E-08
	Yttrium-90 (^{90}Y)	2.28E-09	2.91E-09
Technetium-99 (^{99}Tc)		2.25E-09	3.95E-10
Tin-126 (^{126}Sn)		2.69E-08	5.27E-09
	Antimony-126m (^{126m}Sb)	9.17E-12	2.54E-11
	Antimony-126 (^{126}Sb)	3.17E-09	2.89E-09
Iodine-129 (^{129}I)		4.69E-08	7.46E-08
Cesium-135 (^{135}Cs)		1.23E-09	1.91E-09
Cesium-137 (^{137}Cs)		8.63E-09	1.35E-08
	Barium-137m (^{137m}Ba)	– [b]	– [b]
Thorium Series (4n)			
Plutonium-240 (^{240}Pu)		1.16E-04	9.56E-07
Uranium-236 (^{236}U)		3.39E-05	7.26E-08
Thorium-232 (^{232}Th)		4.43E-04	7.38E-07
Radium-228 (^{228}Ra)		1.29E-06	3.88E-07
	Actinium-228 (^{228}Ac)	8.33E-08	5.85E-10
Uranium-232 (^{232}U)		1.78E-04	3.54E-07
Thorium-228 (^{228}Th)		9.23E-05	1.07E-07
	Radium-224 (^{224}Ra)	8.53E-07	9.89E-08
	Radon-220 (^{220}Rn)	– [b]	– [b]
	Polonium-216 (^{216}Po)	– [b]	– [b]
	Lead-212 (^{212}Pb)	4.56E-08	1.23E-08
	Bismuth-212 (^{212}Bi)	5.83E-09	2.87E-10
	Polonium-212 (^{212}Po)	– [c]	– [c]
	Thallium-208 (^{208}Tl)	– [c]	– [c]
Neptunium Series (4n+1)			
Americium-241 (^{241}Am)		1.20E-04	9.84E-07
Neptunium-237 (^{237}Np)		1.46E-04	1.20E-06
	Protactinium-233 (^{233}Pa)	2.58E-09	9.81E-10
Uranium-233 (^{233}U)		3.66E-05	7.81E-08
Thorium-229 (^{229}Th)		5.80E-04	9.54E-07
	Radium-225 (^{225}Ra)	2.10E-06	1.04E-07
	Actinium-225 (^{225}Ac)	2.92E-06	3.00E-08
	Francium-221 (^{221}Fr)	– [b]	– [b]
	Astatine-217 (^{217}At)	– [b]	– [b]
	Bismuth-213 (^{213}Bi)	4.63E-09	1.95E-10
	Polonium-213 (^{213}Po)	– [b]	– [b]
	Thallium-209 (^{209}Tl)	– [b]	– [b]
	Lead-209 (^{209}Pb)	2.56E-11	5.75E-11

Table 6.5-2. Dose Conversion Factors for Inhalation and Ingestion of Radionuclides of Interest (continued)

Primary Radionuclide	Short-lived Decay Product	Dose Conversion Factors (Sv/Bq)	
		Inhalation	Ingestion
Uranium Series (4n+2)			
Plutonium-242 (^{242}Pu)		1.11E-04	9.08E-07
Uranium-238 (^{238}U)		3.20E-05	6.88E-08
	Thorium-234 (^{234}Th)	9.47E-09	3.69E-09
	Protactinium-234m (^{234m}Pa)	–[b]	–[b]
	Protactinium-234 (^{234}Pa)	2.20E-10	5.84E-10
Plutonium-238 (^{238}Pu)		1.06E-04	8.65E-07
Uranium-234 (^{234}U)		3.58E-05	7.66E-08
Thorium-230 (^{230}Th)		8.80E-05	1.48E-07
Radium-226 (^{226}Ra)		2.32E-06	3.58E-07
	Radon-222 (^{222}Rn)	–[b]	–[b]
	Polonium-218 (^{218}Po)	–[b]	–[b]
	Lead-214 (^{214}Pb)	2.11E-09	1.69E-10
	Astatine-218 (^{218}At)	–[b]	–[b]
	Bismuth-214 (^{214}Bi)	1.78E-09	7.64E-11
	Polonium-214 (^{214}Po)	–[b]	–[b]
	Thallium-210 (^{210}Tl)	–[b]	–[b]
Lead-210 (^{210}Pb)		3.67E-06	1.45E-06
	Bismuth-210 (^{210}Bi)	5.29E-08	1.73E-09
	Polonium-210 (^{210}Po)	2.54E-06	5.14E-07
Actinium Series (4n+3)			
Americium-243 (^{243}Am)		1.19E-04	9.79E-07
	Neptunium-239 (^{239}Np)	6.78E-10	8.82E-10
Plutonium-239 (^{239}Pu)		1.16E-04	9.56E-07
Uranium-235 (^{235}U)		3.32E-05	7.19E-08
	Thorium-231 (^{231}Th)	2.37E-10	3.65E-10
Protactinium-231 (^{231}Pa)		3.47E-04	2.86E-06
Actinium-227 (^{227}Ac)		1.81E-03	3.80E-06
	Thorium-227 (^{227}Th)	4.37E-06	1.03E-08
	Francium-223 (^{223}Fr)	1.68E-09	2.33E-09
	Radium-223 (^{223}Ra)	2.12E-06	1.78E-07
	Radon-219 (^{219}Rn)	–[b]	–[b]
	Polonium-215 (^{215}Po)	–[b]	–[b]
	Lead-211 (^{211}Pb)	2.35E-09	1.42E-10
	Bismuth-211 (^{211}Bi)	–[b]	–[b]
	Thallium-207 (^{207}Tl)	–[b]	–[b]
	Polonium-211 (^{211}Po)	–[b]	–[b]

SOURCE: Eckerman et al. 1988 [101069], Tables 2.1 and 2.2

NOTES: DCFs are in units of Sv/Bq. 1 Sv = 100 rem; 1 Ci = 3.7×10^{10} Bq.

[a] Two values of DCF for ^{90}Sr are given in the source document: one for $SrTiO_3$ and one for all other compounds. Because $SrTiO_3$ is not a common compound and is unlikely to be present in the biosphere, the value for all other compounds was used (Rittmann 1993 [107744], p. 6) .

[b] Eckerman et al. 1988 [101069] does not include DCFs for the short-lived radionuclides. The contribution from the short-lived decay products resulting from the decay of a longer lived parent radionuclide in the human body is included together with the parent radionuclide DCF. For radon, the short-lived decay products are included in the DCF for the parent radionuclide, as described in Section 6.5.4.

[c] Not provided.

It is customary in radiological assessments that the DCFs for inhalation and ingestion are represented by fixed values and the same approach is recommended for the biosphere model although there are many sources of uncertainty associated with the dosimetric models. These uncertainties are described in NCRP Commentary No. 15 (NCRP 1998 [160160]). Specifically, the estimated reliability of the DCFs for inhalation and ingestion based on ICRP-30 methodology can be found in the NCRP Commentary (NCRP 1998 [160160], Table 8.2). The results of the NCRP evaluation indicate that for many radionuclides considered in this analysis, the DCFs are poorly known and that the true values for at least 90 percent of the population may be as much as a factor of 10 higher or lower than the values recommended by ICRP in Publication 30 (NCRP 1998 [160160], Table 8-2).

6.5.3.2 Dose Coefficients for Exposure to Contaminated Soil

The source of dose coefficients for exposure to contaminated soil is FGR 12 (Eckerman and Ryman 1993 [107684]). From this report, the biosphere model uses dose coefficients for exposure to contaminated ground surface and to soil contaminated to an infinite depth. These dose coefficients are listed in Table 6.5-3.

Table 6.5-3. Dose Coefficients for Exposure to Contaminated Soil for Radionuclides of Interest

Primary Radionuclide	Short-lived Decay Product	Dose Coefficient	
		Ground Surface Sv/s per Bq/m^2	Infinite Depth Sv/s per Bq/m^3
Carbon-14 (^{14}C)		1.61E-20	7.20E-23
Chlorine-36 (^{36}Cl)		6.73E-19	1.28E-20
Selenium-79 (^{79}Se)		2.07E-20	9.96E-23
Strontium-90 (^{90}Sr)		2.84E-19	3.77E-21
	Yttrium-90 (^{90}Y)	5.32E-18	1.28E-19
Technetium-99 (^{99}Tc)		7.80E-20	6.72E-22
Tin-126 (^{126}Sn)		5.47E-17	7.89E-19
	Antimony-126m (^{126m}Sb)	1.52E-15	4.98E-17
	Antimony-126 (^{126}Sb)	2.78E-15	9.16E-17
Iodine-129 (^{129}I)		2.58E-17	6.93E-20
Cesium-135 (^{135}Cs)		3.33E-20	2.05E-22
Cesium-137 (^{137}Cs)		2.85E-19	4.02E-21
	Barium-137m (^{137m}Ba)	5.86E-16	1.93E-17
Thorium Series (4n)			
Plutonium-240 (^{240}Pu)		8.03E-19	7.85E-22
Uranium-236 (^{236}U)		6.50E-19	1.15E-21
Thorium-232 (^{232}Th)		5.51E-19	2.79E-21
Radium-228 (^{228}Ra)		0.00E+00	0.00E+00
	Actinium-228 (^{228}Ac)	9.28E-16	3.20E-17
Uranium-232 (^{232}U)		1.01E-18	4.83E-21
Thorium-228 (^{228}Th)		2.35E-18	4.25E-20
	Radium-224 (^{224}Ra)	9.57E-18	2.74E-19
	Radon-220 (^{220}Rn)	3.81E-19	1.23E-20
	Polonium-216 (^{216}Po)	1.65E-20	5.58E-22
	Lead-212 (^{212}Pb)	1.43E-16	3.77E-18
	Bismuth-212 (^{212}Bi)	1.79E-16	6.27E-18
	Polonium-212 (^{212}Po)	0.00E+00	0.00E+00
	Thallium-208 (^{208}Tl)	2.98E-15	1.23E-16
Neptunium Series (4n+1)			
Americium-241 (^{241}Am)		2.75E-17	2.34E-19
Neptunium-237 (^{237}Np)		2.87E-17	4.17E-19
	Protactinium-233 (^{233}Pa)	1.95E-16	5.46E-18
Uranium-233 (^{233}U)		7.16E-19	7.48E-21
Thorium-229 (^{229}Th)		8.54E-17	1.72E-18
	Radium-225 (^{225}Ra)	1.33E-17	5.90E-20
	Actinium-225 (^{225}Ac)	1.58E-17	3.41E-19
	Francium-221 (^{221}Fr)	2.98E-17	8.22E-19
	Astatine-217 (^{217}At)	3.03E-19	9.49E-21
	Bismuth-213 (^{213}Bi)	1.32E-16	4.10E-18
	Polonium-213 (^{213}Po)	0.00E+00	0.00E+00
	Thallium-209 (^{209}Tl)	1.90E-15	6.92E-17
	Lead-209 (^{209}Pb)	3.01E-19	4.14E-21

Table 6.5-3. Dose Coefficients for Exposure to Contaminated Soil for Radionuclides of Interest (continued)

Primary Radionuclide	Short-lived Decay Product	Dose Coefficient	
		Ground Surface Sv/s per Bq/m^2	Infinite Depth Sv/s per Bq/m^3
Uranium Series (4n+2)			
Plutonium-242 (^{242}Pu)		6.67E-19	6.85E-22
Uranium-238 (^{238}U)		5.51E-19	5.52E-22
	Thorium-234 (^{234}Th)	8.32E-18	1.29E-19
	Protactinium-234m (^{234m}Pa)	1.53E-17	4.80E-19
	Protactinium-234 (^{234}Pa)	1.84E-15	6.18E-17
Plutonium-238 (^{238}Pu)		8.38E-19	8.10E-22
Uranium-234 (^{234}U)		7.48E-19	2.15E-21
Thorium-230 (^{230}Th)		7.50E-19	6.47E-21
Radium-226 (^{226}Ra)		6.44E-18	1.70E-19
	Radon-222 (^{222}Rn)	3.95E-19	1.26E-20
	Polonium-218 (^{218}Po)	8.88E-21	3.02E-22
	Lead-214 (^{214}Pb)	2.44E-16	7.18E-18
	Astatine-218 (^{218}At)	4.18E-18	3.13E-20
	Bismuth-214 (^{214}Bi)	1.41E-15	5.25E-17
	Polonium-214 (^{214}Po)	8.13E-20	2.75E-21
	Thallium-210 (^{210}Tl)	–	–
Lead-210 (^{210}Pb)		2.48E-18	1.31E-20
	Bismuth-210 (^{210}Bi)	1.05E-18	1.93E-20
	Polonium-210 (^{210}Po)	8.29E-21	2.80E-22
Actinium Series (4n+3)			
Americium-243 (^{243}Am)		5.35E-17	7.60E-19
	Neptunium-239 (^{239}Np)	1.63E-16	4.03E-18
Plutonium-239 (^{239}Pu)		3.67E-19	1.58E-21
Uranium-235 (^{235}U)		1.48E-16	3.86E-18
	Thorium-231 (^{231}Th)	1.85E-17	1.95E-19
Protactinium-231 (^{231}Pa)		4.07E-17	1.02E-18
Actinium-227 (^{227}Ac)		1.57E-19	2.65E-21
	Thorium-227 (^{227}Th)	1.04E-16	2.79E-18
	Francium-223 (^{223}Fr)	5.65E-17	1.06E-18
	Radium-223 (^{223}Ra)	1.28E-16	3.23E-18
	Radon-219 (^{219}Rn)	5.49E-17	1.65E-18
	Polonium-215 (^{215}Po)	1.74E-19	5.44E-21
	Lead-211 (^{211}Pb)	5.08E-17	1.64E-18
	Bismuth-211 (^{211}Bi)	4.58E-17	1.37E-18
	Thallium-207 (^{207}Tl)	3.76E-18	1.06E-19
	Polonium-211 (^{211}Po)	7.61E-18	2.55E-19

SOURCE: Eckerman and Ryman 1993 [107684], Tables III.3 and III.7

6.5.3.3 Dose Coefficients for Air Submersion and for Water Immersion

Dose coefficients for external exposure to radionuclides in air (air submersion) and in water (water immersion) recommended for use in the biosphere model are listed in Table 6.5-4. The source of these dose coefficients is FGR 12 (Eckerman and Ryman 1993 [107684]).

Table 6.5-4. Dose Coefficients for Air Submersion and Water Immersion for Radionuclides of Interest

Primary Radionuclide	Short-lived Decay Product	Dose Coefficient	
		Air Submersion Sv/s per Bq/m^3	Water Immersion Sv/s per Bq/m^3
Carbon-14 (^{14}C)		2.24E-19	4.39E-22
Chlorine-36 (^{36}Cl)		2.23E-17	4.48E-20
Selenium-79 (^{79}Se)		3.03E-19	5.93E-22
Strontium-90 (^{90}Sr)		7.53E-18	1.46E-20
	Yttrium-90 (^{90}Y)	1.90E-16	3.63E-19
Technetium-99 (^{99}Tc)		1.62E-18	3.14E-21
Tin-126 (^{126}Sn)		2.11E-15	4.76E-18
	Antimony-126m (^{126m}Sb)	7.50E-14	1.63E-16
	Antimony-126 (^{126}Sb)	1.37E-13	2.99E-16
Iodine-129 (^{129}I)		3.80E-16	8.91E-19
Cesium-135 (^{135}Cs)		5.65E-19	1.10E-21
Cesium-137 (^{137}Cs)		7.74E-18	1.49E-20
	Barium-137m (^{137m}Ba)	2.88E-14	6.26E-17
Thorium Series (4n)			
Plutonium-240 (^{240}Pu)		4.75E-18	1.11E-20
Uranium-236 (^{236}U)		5.01E-18	1.16E-20
Thorium-232 (^{232}Th)		8.72E-18	1.99E-20
Radium-228 (^{228}Ra)		0.00E+00	0.00E+00
	Actinium-228 (^{228}Ac)	4.78E-14	1.04E-16
Uranium-232 (^{232}U)		1.42E-17	3.22E-20
Thorium-228 (^{228}Th)		9.20E-17	2.05E-19
	Radium-224 (^{224}Ra)	4.71E-16	1.03E-18
	Radon-220 (^{220}Rn)	1.85E-17	4.03E-20
	Polonium-216 (^{216}Po)	8.29E-19	1.80E-21
	Lead-212 (^{212}Pb)	6.87E-15	1.52E-17
	Bismuth-212 (^{212}Bi)	9.24E-15	2.00E-17
	Polonium-212 (^{212}Po)	0.00E+00	0.00E+00
	Thallium-208 (^{208}Tl)	1.77E-13	3.84E-16
Neptunium Series (4n+1)			
Americium-241 (^{241}Am)		8.18E-16	1.88E-18
Neptunium-237 (^{237}Np)		1.03E-15	2.32E-18
	Protactinium-233 (^{233}Pa)	9.35E-15	2.05E-17
Uranium-233 (^{233}U)		1.63E-17	3.64E-20
Thorium-229 (^{229}Th)		3.83E-15	8.56E-18
	Radium-225 (^{225}Ra)	2.79E-16	6.49E-19
	Actinium-225 (^{225}Ac)	7.21E-16	1.61E-18

Table 6.5-4. Dose Coefficients for Air Submersion and Water Immersion for Radionuclides of Interest (continued)

Primary Radionuclide	Short-lived Decay Product	Dose Coefficient	
		Air Submersion Sv/s per Bq/m^3	Water Immersion Sv/s per Bq/m^3
	Francium-221 (^{221}Fr)	1.46E-15	3.22E-18
	Astatine-217 (^{217}At)	1.48E-17	3.22E-20
	Bismuth-213 (^{213}Bi)	6.39E-15	1.39E-17
	Polonium-213 (^{213}Po)	0.00E+00	0.00E+00
	Thallium-209 (^{209}Tl)	1.02E-13	2.22E-16
	Lead-209 (^{209}Pb)	8.12E-18	1.57E-20
Uranium Series (4n+2)			
Plutonium-242 (^{242}Pu)		4.01E-18	9.35E-21
Uranium-238 (^{238}U)		3.41E-18	7.95E-21
	Thorium-234 (^{234}Th)	3.38E-16	7.64E-19
	Protactinium-234m (^{234m}Pa)	7.19E-16	1.52E-18
	Protactinium-234 (^{234}Pa)	9.34E-14	2.03E-16
Plutonium-238 (^{238}Pu)		4.88E-18	1.14E-20
Uranium-234 (^{234}U)		7.63E-18	1.75E-20
Thorium-230 (^{230}Th)		1.74E-17	3.94E-20
Radium-226 (^{226}Ra)		3.15E-16	6.95E-19
	Radon-222 (^{222}Rn)	1.19E-17	4.16E-20
	Polonium-218 (^{218}Po)	4.48E-19	9.71E-22
	Lead-214 (^{214}Pb)	1.18E-14	2.59E-17
	Astatine-218 (^{218}At)	1.19E-16	2.75E-19
	Bismuth-214 (^{214}Bi)	7.65E-14	1.66E-16
	Polonium-214 (^{214}Po)	4.08E-18	8.85E-21
	Thallium-210 (^{210}Tl)	–	–
Lead-210 (^{210}Pb)		5.64E-17	1.31E-19
	Bismuth-210 (^{210}Bi)	3.29E-17	6.33E-20
	Polonium-210 (^{210}Po)	4.16E-19	9.03E-22
Actinium Series (4n+3)			
Americium-243 (^{243}Am)		2.18E-15	4.94E-18
	Neptunium-239 (^{239}Np)	7.69E-15	1.70E-17
Plutonium-239 (^{239}Pu)		4.24E-18	9.60E-21
Uranium-235 (^{235}U)		7.20E-15	1.59E-17
	Thorium-231 (^{231}Th)	5.22E-16	1.18E-18
Protactinium-231 (^{231}Pa)		1.72E-15	3.78E-18
Actinium-227 (^{227}Ac)		5.82E-18	1.30E-20
	Thorium-227 (^{227}Th)	4.88E-15	1.07E-17
	Francium-223 (^{223}Fr)	2.29E-15	5.11E-18
	Radium-223 (^{223}Ra)	6.09E-15	1.35E-17
	Radon-219 (^{219}Rn)	2.68E-15	5.85E-18
	Polonium-215 (^{215}Po)	8.43E-18	1.84E-20
	Lead-211 (^{211}Pb)	2.49E-15	5.41E-18
	Bismuth-211 (^{211}Bi)	2.22E-15	4.85E-18
	Thallium-207 (^{207}Tl)	1.62E-16	3.38E-19
	Polonium-211 (^{211}Po)	3.81E-16	8.27E-19

SOURCE: Eckerman and Ryman 1993 [107684], Tables III.1 and III.2

6.5.4 Radon Doses

The DCF for inhalation of ^{222}Rn decay products was calculated based on the data from FGR 11 (Eckerman et al. 1988 [101069] and ICRP 1981 [163051]). The function of the DCF for radon, $DCF_{inh,Rn\text{-}222,n}$ in the biosphere model is to convert the exposure to radon decay products to dose (CEDE) for a unit (1 Bq/m^3) radon gas activity concentration in air and for a unit breathing rate (1 m^3/hr) (BSC 2003 [160699], Section 6.4.8.4). This DCF for inhalation of ^{222}Rn decay products, can be derived based on the following:

- The potential alpha energy concentration (PAEC)-to-dose conversion factor for ^{222}Rn decay products is 0.010 Sv (1 rem) per working level month (ICRP 1981 [163051], p. 15)

- 1 working level month (WLM) corresponds to an exposure to radon decay products whose PAEC is equal to 1 working level (WL) for a period of 1 working month (approximately 170 working hours) (10 CFR 20.1003 [104787]).

- The PAEC of 1 WL corresponds to any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy, which is approximately the alpha energy released from the decay of the short-lived decay products in equilibrium with 100 pCi of ^{222}Rn (10 CFR 20.1003 [104787]).

- The conversion factor of (1 rem)/(1 WLM) was developed for workers whose breathing rate is equal to 1.2 m^3/hr (ICRP 1981 [163051], pp. 7 and 15, Eckerman et al. 1988 [101069], p. 10). Because the DCF for inhalation of ^{222}Rn applies to a unit breathing rate, an additional correction factor of 1/1.2 m^3/hr is used.

The DCF for inhalation of ^{222}Rn can thus be derived as follows:

$$DCF_{inh,Rn-222,n} = \frac{1\,\text{rem}}{1\,\text{WLM}}\,\frac{1\,\text{WLM}}{170\,\text{WL h}}\,\frac{1\,\text{WL}}{100\,\text{pCi/L}}\,\frac{1\,\text{pCi/L}}{37\,\text{Bq/m}^3}\,\frac{0.01\,\text{Sv}}{1\,\text{rem}}\,\frac{1}{1.2\,\text{m}^3/\text{h}} \times EF_{Rn-222,n} =$$

$$= 1.33 \times 10^{-8}\, EF_{Rn-222,n}\,\frac{\text{Sv}}{\text{Bq}} = DCF_{inh,Rn-222}\; EF_{Rn-222,n}$$

where

$EF_{Rn\text{-}222,\,n}$	=	equilibrium factor for ^{222}Rn decay products for the environment *n* (dimensionless)
$DCF_{inh,\,Rn\text{-}222}$	=	DCF for inhalation of ^{222}Rn decay products in equilibrium with radon gas (1.33×10^{-8} Sv/Bq, rounded up to three significant digits)

The equilibrium factor, $EF_{Rn\text{-}222}$, permits estimation of PAEC from the measurement of radon gas (here ^{222}Rn). It is defined as the ratio of the actual PAEC to the PAEC that would prevail if all the decay products in the (^{222}Rn) series were in equilibrium with the parent radon. The equilibrium factor depends on the environment and is typically higher for the outdoor environment than indoor (UNSCEAR 2000 [158644], pp. 103-104).

6.5.5 Dependence of Inhalation Dose Conversion Factors on Particle Sizes

To estimate inhalation exposure to airborne particulates one needs to know the particle size distribution because the DCFs vary with the particle size. It is generally considered that the particles that may become resuspended are associated with the aerodynamic diameters of less than 100 µm (Anspaugh et al. 1975 [151548], p. 572). The smallest of these particles (< ~ 10 µm) may be suspended for a considerable amount of time (Nicholson 1988 [160116], p. 2642).

6.5.5.1 Particle Size Distribution of Environmental Aerosols

The size distribution of resuspended particles depends not only on the characteristic of the site but also on the activities that result in generation of airborne particulates. Shinn (1992 [160115], p. 1190) indicates that average median aerodynamic diameter of particles produced by resuspension of material deposited on the ground is in the range between 2 and 6 µm. Dorrian (1997 [159476], pp. 117, 129) concluded that the median value of AMAD for resuspended aerosols was 6 µm. The measurements by Shinn (1992 [160115]) include experiments performed at the Nevada Test Site. A coarse component (> ~ 2 µm), with median diameter of about 15 µm is sometimes also found when the soil is disturbed or when very strong winds are present (NCRP 1999 [155894], p. 67). This coarse component should be considered transient because the gravitational settling velocities of the coarse particles are greater than the suspension velocities and their residence times in the atmosphere are short (NCRP 1999 [155894], p. 67). In general, the ratio of total suspended particulates to the PM_{10} fraction (particulates with the median aerodynamic diameter less than 10 µm) increases under disturbed conditions (NCRP 1999 [155894], p. 67). The generic recommended particle size distribution is lognormal with a median diameter in the range of 2 to 6 µm and a GSD of about five (NCRP 1999 [155894], p. 68). Such distribution applies to the long-term, average conditions. The particle size distribution of airborne activity may be different from the distribution of the suspended soil dust, particularly if the radioactive particles are preferentially bound to a specific size range of the soil particles. This may be the case for the volcanic ash exposure scenario, as described later in this section.

Short-term particle size distributions may include a larger contribution from the coarse component, compared to the average conditions, especially during or immediately following a dust generating activity. For example, agricultural activities may involve generation of high levels of dust. In one study conducted in arid agricultural regions in California, it was observed that dust particles were relatively large and that the largest proportion of the dust belonged to the extrathoracic fraction (> 10 µm) (Nieuwenhuijsen et al. 1998 [150855], p. 36). The average mass median aerodynamic diameter measured during various agricultural operations was 49 µm (Nieuwenhuijsen et al. 1998 [150855], p. 36). The proportion of small particles (< 10 µm) for most activities was less than 10% and generally was lower for dustier activities. Another study of natural aerosols in the arid southwestern United States concluded that near-surface aerosol is comprised to two modes: a wind-derived supermicron component which is likely soil-derived and local in origin and a submicron component that is likely a product of long-range atmospheric transport (Pinnick et al. 1993 [160312], pp. 2651 and 2664). The supermicron component dominates the total aerosol mass while submicron mode contributes little to the aerosol mass. During the disturbed conditions, such as dust storm, there is an increase in concentration of supermicron aerosols (coarse mode with particle sizes up to 100 μm) that consists almost exclusively of particles of the parent soil. The submicron aerosol concentration was nearly unaffected by the disturbed conditions (Pinnick et al. 1993 [160312], p. 2659). Similar findings resulted from the study by Whitby as reported in EPA (1996 [160121], p. 3-161, Figure 3-22), who concluded that the concentration of particles smaller than 2.5 μm in diameter was not affected by the strong winds. The review of the available information on airborne particulates, with emphasis on the coarse mode, concluded that the coarse model could be reasonably well described by a lognormal distribution with a mass median aerodynamic diameter of 15 to 25 μm and a GSD of approximately two (EPA 1996 [160121], p. 3-160). Thus for a freshly-generated coarse model aerosol, only about 1% of the mass would be less than 2.5 μm and only about 0.1% would be less than 1.0 μm in diameter (EPA 1996 [160121], pp. 3-160 to 3-161). Based on the reviewed literature (EPA 1996 [160121], Sections 3.7.5 - 3.7.8; Nieuwenhuijsen et al. 1998 [150855]; Pinnick et al. 1993 [160312]), the airborne particles originating from the local soils range in size from about 0.1 μm to about 100 μm.

Particle size distribution for the indoor environment differs from that characteristic of the outdoor environment. Under typical conditions, aerosols in the coarse mode (> 2 μm) are only likely to give rise to exposures to people who are outdoors and close to the site of contamination (Dorrian 1997 [159476], p. 129-130). In the indoor environment, concentration of large particles is significantly depleted in comparison to the outdoor environment and particles larger than 5 μm would be decreasingly likely to penetrate indoors (Dorrian 1997 [159476], p. 130).

Volcanic ash exposure scenario involves generation of contaminated ash particles that can be transported in the atmosphere and subsequently deposited on the ground. Explosive eruptive styles of Quaternary volcanoes in the Yucca Mountain region include both strombolian and violent strombolian (BSC 2001 [160130], p. 43). The distribution of the average size ash particles resulting from a volcanic eruption at Yucca Mountain is defined as logtriangular with a minimum of 10 μm, a mode of 100 μm, and a maximum of 10,000 μm. The distribution of mean ash particle standard deviation is uniform from 1-3 phi units, which are defined as a negative logarithm in base 2 of the particle diameter in millimeters (DTN: LA0107GV831811.001 [160708]). This distribution is consistent with the particle size distributions for the analogue volcanoes (Tolbachik and Cerro Negro) of the violent strombolian type (BSC 2001 [160130], p. 44).

The distribution of the waste particles is log-triangular with a minimum waste particle size of 1 μm, the mode of 20 μm, and the maximum of 500 μm (DTN: SN0109T0502900.005 [156272]; BSC 2001 [157876], p. 38). Based on the particle size, only a small fraction of particles (the smallest predicted average ash sizes have a very low probability of occurrence) would be available for resuspension. This distribution was based in part on measurements of particles size distributions from Cerro Negro eruption, which was a violent strombolian eruption, the type predicted at Yucca Mountain (BSC 200l [160130], Section 6.5.1).

During volcanic eruption intersecting the repository, the waste becomes incorporated into the ash with the incorporation ratio of 0.3 (BSC 2001 [157876], p. 24). The incorporation ratio describes the ratio of ash/waste particle sizes that can be attached together. The modeling of the transport also includes an assumption that all waste particles corresponding to values below incorporation ratio are attached to ash particles for transport. Incorporation of waste particles requires ash particles of a certain size or larger. Thus, larger ash particles will carry more waste mass and smaller ash particles will carry less or maybe even no waste mass (BSC 2001 [157876], p. 24).

The model for atmospheric transport of contaminated volcanic ash (ASHPLUME) is appropriate for particles of mean diameter greater than 15-30 µm (Jarzemba et al. 1997 [100987], p. 2-2). Although the model is useful for calculating the distribution of vast majority of ash (typical mean diameter of ash particle after an eruption is generally much greater than 15 µm), it does not address well the particles in the respirable (< 4 µm) and thoracic (< 10 µm) size range, which are more important for the evaluation of inhalation doses. Therefore, the information from the analog volcano was used to estimate the airborne particle sizes for the evaluation of inhalation exposure of the receptor. The measurements performed at about 21 km from the Cerro Negro volcano indicate that only about 20% of the deposited ash particles by weight are in the inhalable particle size range (< 100 µm) (Reamer and Williams 2000 [154597], Attachment 17 of Appendix 4). Particles in this size range can become airborne either due to natural processes or as the result of the human surface disturbing activities.

The suspendibility of particles depends of their aerodynamic properties. Therefore it can be reasonably expected that the range of the aerodynamic diameters of the suspended ash particles will be similar to the range of suspended soil particles described above, although the mass particle size ranges may be different due to the differences in particle densities and shapes. The same range of particle sizes is also expected for the future climate considered within the applicability limits of the biosphere model.

6.5.5.2 Dosimetric Considerations for Airborne Particulates

From the human health perspective, particulates can be classified into inhalable, thoracic and respirable, according to their entrance and deposition in the various compartment of the respiratory system. Inhalable particles refer to those that enter the respiratory tract, including the head airways region (anterior and posterior nose, larynx, pharynx and mouth). Thoracic particles refer to particles that reach the lung airways and the gas-exchange region (bronchial, bronchiolar, and alveolar regions), and respirable particles are those that reach the gas-exchange region (alveolar region) (EPA 1996 [160121], p. 3-11; ICRP 1994 [153705], pp. 8-11). The term extrathoracic particles used later in this section refers to particles that do not reach the lung airways and the gas exchange region.

The most important parameter determining the particle's aerodynamic behavior and respiratory tract deposition is its aerodynamic equivalent diameter, which depends on particle density and shape (Dorrian 1997 [159476], p. 117). The DCFs for inhalation of airborne contaminants depend on their aerodynamic diameter. To ensure consistent use, the inhalation DCFs are tabulated for particles with a given AMAD. AMAD is defined as the diameter of a unit-density sphere having the same terminal settling velocity in air as the aerosol particle whose activity is the median for the entire aerosol (Eckerman et al. 1988 [101069], p. 219), i.e., 50% of an aerosol's activity is associated with particles whose aerodynamic equivalent diameter is greater than the AMAD. Respiratory tract deposition of radioactive aerosols is related to the AMAD of the particle size distribution and is relatively insensitive to the GSD of the distribution.

The density of most of the environmental particles is greater than unity. Therefore such particles are aerodynamically equivalent to larger particles of unit density (aerodynamic diameter is directly proportional to the square root of the particle density) (EPA 1996 [160121], p. 3-9).

The size distribution of resuspended soil particles may be described as lognormal bimodal with one mode at 2-5 µm and another mode at 30 to 60 µm (EPA 1996 [160121], p. 3-36) and the size range of the particles originating in local soil is typically between 0.1 and 100 µm (see Section 6.5.5.1). The inhalation DCFs based on the ICRP-30 dosimetric methods are most commonly tabulated for particulates whose diameter is distributed lognormally with an AMAD of 1 µm (ICRP 1979 [110386], Eckerman et al. 1988 [101069]). Using the respiratory tract model of ICRP Publication 30 (ICRP 1979 [110386], pp. 23-29) the DCFs for 1-µm particles can be converted to DCFs for other particle sizes, as described below.

The conversion method is based on the formula (ICRP 1979 [110386], Equation 5.8) that calculates the committed dose equivalent in an organ T for particles of a given AMAD, H_T (*AMAD*), as a fraction of the committed dose equivalent in this organ for 1-µm particles, H_T (1 µm):

$$\frac{H_T(AMAD)}{H_T(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_P\frac{D_P(AMAD)}{D_P(1\ \mu m)} \qquad \text{(Eq. 6.5-1)}$$

where

f_{N-P}	=	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the naso-pharyngeal, *N-P*, region of the respiratory tract
$D_{N-P}(AMAD)$	=	deposition probability in the *N-P* region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1)
$D_{N-P}(1\ \mu m)$	=	deposition probability in the *N-P* region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1)
f_{T-B}	=	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the tracheo-bronchial, *T-B*, region of the respiratory tract
$D_{T-B}(AMAD)$	=	deposition probability in the *T-B* region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1)
$D_{T-B}(1\ \mu m)$	=	deposition probability in the *T-B* region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1)
f_P	=	fraction of the committed dose equivalent in the reference tissue resulting from deposition in the pulmonary, *P*, region of the respiratory tract
$D_P(AMAD)$	=	deposition probability in the *P* region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1)

$D_P(1\ \mu m)$ = deposition probability in the P region of the respiratory tract for a given AMAD (from ICRP 1979 [110386], Figure 5.1).

The respiratory tract model of ICRP Publication 30 is intended for use with aerosol distributions with AMAD between 0.2 and 10 µm and with GSDs of less than 4.5. Provisional estimates of deposition further extending the size range from 0.1 µm to 20 µm were provided. For distributions with an AMAD of greater than 20 µm it is recommended that the complete deposition in the naso-pharyngeal region be assumed (ICRP 1979 [110386], p. 24). The relationship between the values of $D_{N\text{-}P}$, $D_{T\text{-}B}$, and D_P, representing the fractions of the inhaled particles that are estimated to deposit in the three regions of the respiratory tract, and the aerodynamic sizes of the particles were developed for an adult male involved in light work.

The weighted committed dose equivalent in an organ per intake of unit activity for particles (here 1 Bq) of a given AMAD, $w_T\ H_{T,1}(AMAD)$, can then be calculated by multiplying the ratio obtained using Equation 6.5-1 by the weighted committed dose equivalent in this organ per intake of unit activity for 1 µm particles.

$$w_T\ H_{T,1}(AMAD) = \frac{H_T(AMAD)}{H_T(1\ \mu m)}\ w_T\ H_{T,1}(1\ \mu m) \qquad \text{(Eq. 6.5-2)}$$

where

w_T = organ or tissue weighting factor

The weighted committed dose equivalent for various organs per intake of unit activity for 1-µm particles and the fractions of the committed dose equivalent in these organs or tissues resulting from deposition in various parts of the respiratory tract can be found in Supplements to Parts 1, 2 and 3 of ICRP Publication 30 (ICRP 1978 [101076], pp. 84-85, 192-193, 231-232, 236-237, 289-290, 318, 322-323, 333-334, 356-357, 362, 364-365, 371, 378, 410-411, 414-415, 418-419, 424-425, 456, 466-467; ICRP 1981 [153056], pp. 19, 195, 660-661, 739; ICRP 1982 [153057], pp. 790, 827; ICRP 1982 [163147], pp. 158-159). The committed EDE can then be calculated by summing up the organ-weighted committed dose equivalents. Their sum represents the effective (weighted) dose equivalent for a given AMAD per intake of unit activity by inhalation. This quantity can be compared to the corresponding DCF for 1-µm particles by producing a following ratio of these two quantities:

$$Ratio = \frac{\sum_T w_T\ H_{T,1}(AMAD)}{\sum_T w_T\ H_{T,1}(1\ \mu m)} \qquad \text{(Eq. 6.5-3)}$$

The ratio identified in Equation 6.5-3 is a measure of how closely the DCFs for 1-µm particles represent DCFs for other particle sizes, with the value of 1 meaning that the respective DCFs are equal. Such ratios were calculated for a range of particle sizes corresponding to the expected range of particle sizes for resuspended contaminated soil, i.e., from 0.1 to 100 µm. As noted previously, the model is intended for use with aerosol distributions with AMAD between 0.2 and 10 µm and the values beyond this range are provisional. The results of comparison are summarized in Table 6.5-5. The same information is also presented graphically in Figure 6.5-1. The Excel spreadsheet calculations are shown in Attachment II. The Excel file (file name **Inhalation of large particles.xls**) is provided in Attachment III.

To determine the expected range of the inhalation DCF ratios, a comparison was made for primary radionuclides except ^{14}C, which is inhaled as a gas (CO_2). The decay products of the primary radionuclides were not included in this analysis because the majority of them are either isotopes of the elements already represented by the primary radionuclides (the DCF ratios for isotopes of the same element are the same, as shown in Table 6.5-5) or they are sufficiently short-lived such that their contribution is already accounted for in the DCF of the parent (DCF include contributions from decay products that are generated within the body).

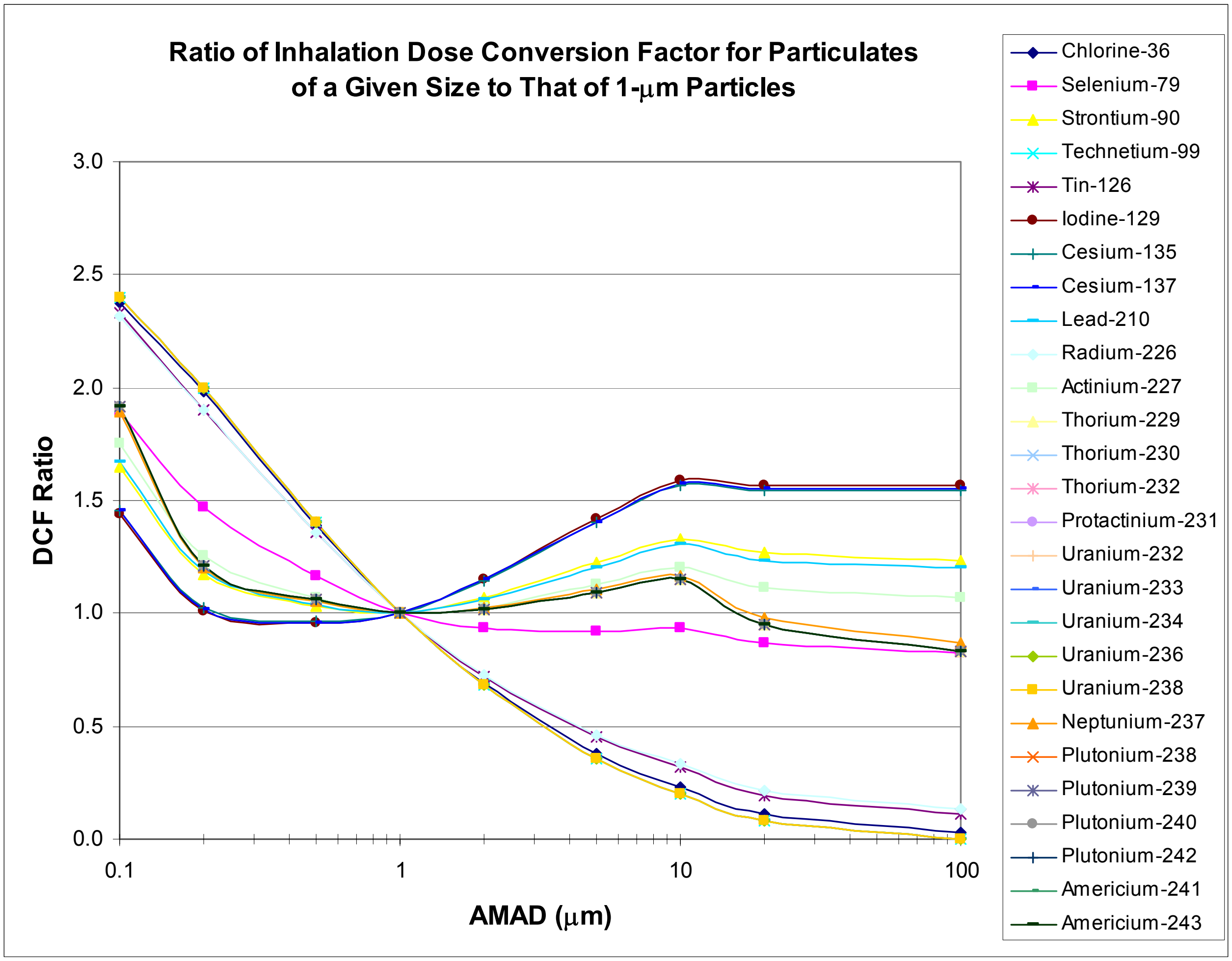
The DCF ratios for 0.1-µm to 100-µm particles range from 0.0 to 2.4. The DCFs are generally higher for the smallest particles. The radionuclides, such as isotopes of uranium, whose DCFs are the highest for small particles also have the lowest DCFs for large particles because of the whole or a large proportion of the dose originating in the lungs [large particles are deposited in the naso-pharyngial region and do not reach the lungs]. The AMAD for the soil-derived airborne particulates for the long-term averages is expected to be in the 2-6 µm range. However, it is anticipated that the majority of the inhalation exposure to the RMEI will occur in the dusty environments associated with relatively large particles. Therefore, the AMADs larger than 1 µm are more appropriate to represent particle size distribution in various environments addressed in the biosphere model. For such particles, the DCF ratios do not exceed 1.6. The contribution to the dose from inhalation of particulates is high for the heavy radionuclides, such as isotopes of neptunium, plutonium, and americium (CRWMS M&O 2001 [152536], Table 16 on p. 73). Isotopes of these elements are also the highest contributors to the all-radionuclide dose for the igneous disruption scenario (DOE 2001 [153849], Figure 4-194). For these radionuclides and AMADs between 0.5 and 100 µm the DCFs ratio is close to 1 and ranges from 0.8 to 1.2.

The DCF ratios needs to be put into perspective considering uncertainties associated with the DCF values. The DCF uncertainties are not customarily included in radiological assessments. For instance, the internal dosimetry methods recommended for a performance assessment by the NRC (2000 [157704], Section 3.3.7.3.1) are based on FGR-11 (Eckerman et al. 1988 [101069]), which does not include consideration of uncertainty in the DCF values. However, the DCFs are subject to uncertainty. The estimated uncertainties in inhalation DCFs for selected radionuclides were tabulated by NCRP (NCRP 1999 [155894], p. 83). For heavy radionuclides, such as ^{210}Pb, ^{210}Po, ^{226}Ra, ^{230}Th, ^{234}U, ^{237}Np, ^{239}Pu, and ^{241}Am, the estimated uncertainty range is quantified as 5 for adult males and up to 10 for other population groups, while for ^{90}Sr and ^{137}Cs, the uncertainty range is estimated at 3 and 2, respectively, for adult males and 5 for other groups (NCRP 1999 [155894], p. 83). The uncertainty range can be interpreted as indicating that the DCF for some individuals may be as much as a given factor higher or lower than the dose factor recommended by ICRP. It also needs to be noted that these uncertainty estimates apply to the new ICRP respiratory tract model, which is considered more realistic than the older, ICRP-30-based model.

Table 6.5-5. Comparison of Inhalation Dose Conversion Factors Between 1-μm Particles and Other Size Particles

Radionuclide	**DCF Ratio (DCF for a Given Size Particles to DCF for 1-μm Particles)[a]**								
	0.1 μm	**0.2 μm**	**0.5 μm**	**1 μm**	**2 μm**	**5 μm**	**10 μm**	**20 μm**	**100 μm**
Chlorine-36	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Selenium-79	1.9	1.5	1.2	1.0	0.9	0.9	0.9	0.9	0.8
Strontium-90	1.7	1.2	1.0	1.0	1.1	1.2	1.3	1.3	1.2
Technetium-99	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Tin-126	2.3	1.9	1.4	1.0	0.7	0.5	0.3	0.2	0.1
Iodine-129	1.4	1.0	1.0	1.0	1.2	1.4	1.6	1.6	1.6
Cesium-135	1.5	1.0	1.0	1.0	1.1	1.4	1.6	1.5	1.5
Cesium-137	1.5	1.0	1.0	1.0	1.1	1.4	1.6	1.6	1.5
Lead-210	1.7	1.2	1.0	1.0	1.1	1.2	1.3	1.2	1.2
Radium-226	2.3	1.9	1.4	1.0	0.7	0.5	0.3	0.2	0.1
Actinium-227	1.8	1.3	1.1	1.0	1.0	1.1	1.2	1.1	1.1
Thorium-229	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Thorium-230	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Thorium-232	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Protactinium-231	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Uranium-232	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-233	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-234	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-236	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-238	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Neptunium-237	1.9	1.2	1.1	1.0	1.0	1.1	1.2	1.0	0.9
Plutonium-238	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-239	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-240	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-242	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Americium-241	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Americium-243	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8

[a] Calculated in Excel file *Inhalation of Large Particles.xls*, shown in Attachment II, from Equations 6.5-1 to 6.5-3 using values from ICRP 1978 [101076], pp. 84-85, 192-193, 231-232, 236-237, 289-290, 318, 322-323, 333-334, 356-357, 362, 364-365, 371, 378, 410-411, 414-415, 418-419, 424-425, 456, 466-467; ICRP 1981 [153056], pp. 19, 195, 660-661, 739; ICRP 1982 [153057], pp. 790, 827; ICRP 1982 [163147], pp. 158-159.



SOURCE: Based on the values shown in Table 6.5-5.

Figure 6.5-1. The Ratio of Inhalation Dose Conversion Factors for Particulates of a Given AMAD to that of 1-µm Particulates

The new respiratory tract model was also used to analyze the appropriateness of the 1-µm AMAD DCFs recommended by the ICRP as a default for indoor or outdoor exposure of the general public (ICRP 1996 [152446], p. 5). This recommendation is considered appropriate for estimating doses to members of the public when particle size distributions are unknown (Dorrian 1997 [159476], p. 130). However, when the exposure is known to have resulted from inhalation of resuspended radioactive aerosols, the AMAD of 5 µm appears to be more realistic for estimating the doses (Dorrian 1997 [159476], p. 117).

As noted previously, the respiratory tract model of ICRP Publication 30 was intended for use with aerosol distributions with AMADs between 0.2 and 10 µm. The new respiratory tract models developed by NCRP (NCRP 1997 [160260]) and ICRP (ICRP 1994 [153705]) extended the range of particle sizes from 0.001 to 100 µm. For the exposure to airborne particulates under disturbed conditions, the majority of particulates is associated with large particles. For such particles (>20 µm), the ICRP model recommends that the complete deposition in the naso-pharyngeal region be assumed (ICRP 1979 [110386], p. 24). The NCRP model, on the other hand, predicts a reduced deposition for very large particles in the upper airways due to the lower inspirability of such particles (NCRP 1998 [160160], p. 37). Inspirability (also called inhalability) is the probability that particles with a particular aerodynamic diameter are able to follow the air stream from outside air into the respiratory tract.

Considering the above, it was concluded that the application of DCFs for particles with AMAD of 1 μm will not underestimate the doses from inhalation of resuspended material and that such DCFs are adequate for use in the biosphere model.

6.6 BUILDING SHIELDING FACTORS

The shielding offered by the floors and walls of the house varies widely depending on the type of construction, height above ground, and other factors. Even for lightly constructed houses (i.e., buildings such as mobile homes with thin walls and floors), the exposure rate from the high-energy gamma emitters is reduced to about 0.4 of the outside value (NCRP 1999 [155894], p. 52). The degree of reduction of indoor exposure relative to outdoor exposure is described by the building shielding factor, which is defined as ratio of dose indoors to dose outdoors. Shielding factors range from 0.001 to 0.5 (with higher values associated with buildings of light construction), with a mean of 0.2 (NCRP 1999 [155894], p. 53). The shielding factors recommended by the NCRP for the use in screening models were calculated for a receptor population consisting of persons living in the most lightly constructed housing. Such shielding factors are appropriate for the Amargosa Valley population because 375 of 422 (88.9%) occupied housing units in the 2000 Census were mobile homes (Bureau of the Census 2002 [159728], Tables H30 and H31). In addition, the 2000 Census data indicated that 91.3% of the total Amargosa Valley population (1043 of 1142 people) lived in mobile homes (Bureau of the Census 2002 [159728], Table H33).

Four different shielding factor values were chosen for different radionuclides depending on the relative penetrability of their emissions (energy and type of radiation emitted) as follows (NCRP 1999 [155894], p. 52). Relative penetrability was determined by comparing the dose coefficients for different geometries of the source and evaluating their differences with assumed radionuclide concentration profile in the soil. For radionuclides with highly penetrating radiations (gamma emitters of energy > 100 keV) a shielding factor of 0.4 was chosen. For low energy gamma (energy < 100 keV) or high-energy beta (average energy > 100 keV) emitters, a shielding factor equal to 0.3 was chosen. For pure beta emitters with average energy < 100 keV, and very low energy gamma emitters with energy < 50 keV, a shielding factor of 0.2 was chosen. For low-energy x-ray emitters (energy < 30 keV), the chosen value of shielding factor is 0.1.

The default value of the shielding factor used in the RESRAD code is 0.7 (Yu et al. 2001 [159465], p. A-8). RESRAD is the code designed to estimate radiation doses and risks from residual radioactive materials in environmental media, including soil (Yu et al. 2001 [159465]). This value implies that the indoor levels of external radiation are only 30% lower than the outdoor levels. The RESRAD authors state that this value is likely to be conservative when applied to scenarios involving low to moderate energy gamma emitters or when applied to well-shielded buildings. The review of the values of shielding factor reported in NCRP (1999 [155894], p. 53) indicates that the shielding factor values are lower than the value of 0.7 used in

RESRAD. Therefore, the shielding factors recommended for the use in screening models are considered appropriate for the biosphere model for evaluation of indoor exposures at home and at work. The list of shielding factors for the primary radionuclides and their decay products is shown in Table 6.6-1. Shielding factor for ^{14}C, ^{210}Tl, ^{212}Po, ^{213}Po, ^{222}Rn, ^{223}At, and ^{228}Ra were not given in NCRP (1999 [155894]). The dose coefficients for ^{212}Po, ^{213}Po, and ^{228}Ra are equal to 0 (Eckerman and Ryman 1993 [107684], Table III.7); therefore, a shielding factor of 0 was selected. For the remaining radionuclides, the chosen value for the shielding factor was based on the type and energy of the radionuclide emissions and the criteria described above.

In the biosphere model, some primary radionuclides are considered together with their short-lived decay products (see Table 6.6-1). For such radionuclides, only one value of shielding factor was assigned, the highest of the values for individual radionuclides.

Table 6.6-1. Shielding Factors for Primary Radionuclides and Their Decay Products

Primary Radionuclide	Short-lived Decay Products	Shielding Factor	Primary Radionuclide	Decay Products	Shielding Factor
Carbon-14 (^{14}C)		0.2 [a]			
Chlorine-36 (^{36}Cl)		0.4			
Selenium-79 (^{79}Se)		0.1			
Strontium-90 (^{90}Sr)		0.3 (0.4) [b]			
	Yttrium-90 (^{90}Y)	0.4			
Technetium-99 (^{99}Tc)		0.2			
Tin-126 (^{126}Sn)		0.4 (0.4) [b]			
	Antimony-126m (^{126m}Sb)	0.4			
	Antimony-126 (^{126}Sb)	0.4			
Iodine-129 (^{129}I)		0.1			
Cesium-135 (^{135}Cs)		0.1			
Cesium-137 (^{137}Cs)		0.3 (0.4) [b]			
	Barium-137m (^{137m}Ba)	0.4			
Thorium Series (4n)			**Neptunium Series (4n+1)**		
Plutonium-240 (^{240}Pu)		0.1	Americium-241 (^{241}Am)		0.2
Uranium-236 (^{236}U)		0.1	Neptunium-237 (^{237}Np)		0.3 (0.4) [b]
Thorium-232 (^{232}Th)		0.2		Protactinium-233 (^{233}Pa)	0.4
Radium-228 (^{228}Ra)		0.0 [a] (0.4) [b]	Uranium-233 (^{233}U)		0.4
	Actinium-228 (^{228}Ac)	0.4	Thorium-229 (^{229}Th)		0.4 (0.4) [b]
Uranium-232 (^{232}U)		0.3		Radium-225 (^{225}Ra)	0.1
Thorium-228 (^{228}Th)		0.4 (0.4) [b]		Actinium-225 (^{225}Ac)	0.4
	Radium-224 (^{224}Ra)	0.4		Francium-221 (^{221}Fr)	0.4
	Radon-220 (^{220}Rn)	0.4		Astatine-217 (^{217}At)	0.4
	Polonium-216 (^{216}Po)	0.4		Bismuth-213 (^{213}Bi)	0.4
	Lead-212 (^{212}Pb)	0.4		Polonium-213 (^{213}Po)	0.0 [a]
	Bismuth-212 (^{212}Bi)	0.4		Thallium-209 (^{209}Tl)	0.4
	Polonium-212 (^{212}Po)	0.0 [a]		Lead-209 (^{209}Pb)	0.3
	Thallium-208 (^{208}Tl)	0.3			

Table 6.6-1. Shielding Factors for Primary Radionuclides and Their Decay Products (continued)

Primary Radionuclide	Short-lived Decay Products	Shielding Factor	Primary Radionuclide	Decay Products	Shielding Factor
Uranium Series (4n+2)			**Actinium Series (4n+3)**		
Plutonium-242 (^{242}Pu)		0.1	Americium-243 (^{243}Am)		0.3 (0.4) [b]
Uranium-238 (^{238}U)		0.1 (0.4) [b]		Neptunium-239 (^{239}Np)	0.4
	Thorium-234 (^{234}Th)	0.3	Plutonium-239 (^{239}Pu)		0.3
	Protactinium-234m (^{234m}Pa)	0.4	Uranium-235 (^{235}U)		0.4
	Protactinium-234 (^{234}Pa)	0.4		Thorium-231 (^{231}Th)	0.3
Plutonium-238 (^{238}Pu)		0.1	Protactinium-231 (^{231}Pa)		0.4
Uranium-234 (^{234}U)		0.2	Actinium-227 (^{227}Ac)		0.4 (0.4) [b]
Thorium-230 (^{230}Th)		0.3		Thorium-227 (^{227}Th)	0.4
Radium-226 (^{226}Ra)		0.4 (0.4) [b]		Francium-223 (^{223}Fr)	0.3
	Radon-222 (^{222}Rn)	0.0 [a]		Radium-223 (^{223}Ra)	0.4
	Polonium-218 (^{218}Po)	0.4		Radon-219 (^{219}Rn)	0.4
	Lead-214 (^{214}Pb)	0.4		Polonium-215 (^{215}Po)	0.4
	Astatine-218 (^{218}At)	0.1		Lead-211 (^{211}Pb)	0.4
	Bismuth-214 (^{214}Bi)	0.4		Bismuth-211 (^{211}Bi)	0.4
	Polonium-214 (^{214}Po)	0.4		Thallium-207 (^{207}Tl)	0.4
	Thallium-210 (^{210}Tl)	0.4 [a]		Polonium-211 (^{211}Po)	0.4
Lead-210 (^{210}Pb)		0.1 (0.4) [b]			
	Bismuth-210 (^{210}Bi)	0.4			
	Polonium-210 (^{210}Po)	0.4			

SOURCE: NCRP 1999 [155894], Appendix C

NOTES:

[a] Shielding factor for ^{14}C, ^{210}Tl, ^{212}Po, ^{213}Po, ^{222}Rn, and ^{228}Ra were not given in NCRP (1999 [155894]). The dose coefficients for ^{212}Po, ^{213}Po, and ^{228}Ra are equal to 0 (Eckerman and Ryman 1993 [107684], Table III.7), so the value of the shielding factor equal to 0 was selected. For the remaining radionuclides, the value of the shielding factor was determined based on the type and energy of the radionuclide emissions and the criteria described above as follows:

^{14}C – beta emitter, average energy <100 keV (Lide and Frederikse 1997 [103178], p. 11-42); shielding factor = 0.2;

^{210}Tl – beta/gamma emitter, gamma energy > 100 keV (Lide and Frederikse 1997 [103178], p. 11-125); shielding factor = 0.4;

^{222}Rn – alpha emitter, no penetrating radiation (Eckerman and Ryman 1993 [107684], Table A.1); shielding factor = 0.0.

[b] For the primary radionuclides considered in the biosphere model together with their short-lived decay products, only one value of shielding factor was assigned, the highest of the values for individual radionuclides. This value is given in parentheses next to the shielding factor for the primary radionuclide.

7. CONCLUSIONS

This section provides a summary of the values of parameters pertaining to the characteristics of the receptor for the biosphere model. These data, which constitute an output of this analysis, are included in the data set identified by the DTN: MO0306SPACRBSM.001.

The values of receptor characteristics were developed specifically for use in the biosphere model and may not be appropriate for other applications. Uncertainties in the parameter values are addressed in the appropriate subsections of Section 6.

7.1 LIFESTYLE CHARACTERISTICS OF THE RECEPTOR

7.1.1 Proportion of Population

Uniform distributions with minimum and maximum values shown in Table 7.1-1 are to be used in biosphere model for proportion of non-workers, commuters, and local outdoor workers. Different distributions are to be used for the groundwater and volcanic ash exposure scenarios. The summary of the values is presented in Table 7.1-1.

Table 7.1-1. Proportion of the Amargosa Valley Population in Occupation Categories

Group	Estimated Proportion	Uniform Distribution	
		Minimum	Maximum
Groundwater Exposure Scenario			
Non-workers	39.2%	34.4%	44.0%
Commuters	39.2%	33.9%	44.5%
Local Outdoor Workers	5.5%	2.9%	8.1%
Local Indoor Workers[a]	16.1%		
Volcanic Ash Exposure Scenario			
Non-workers	39.2%	34.4%	44.0%
Commuters	12.5%	4.9%	16.3%
Local Outdoor Workers	5.5%	2.9%	10.7%
Local Indoor Workers[a]	42.8%		

NOTE: [a] Calculated in the biosphere model as one minus the sum of the other three percentages; therefore a SE and distribution is not presented.

7.1.2 Exposure Times by Population Group and Environment

Lognormal distributions of exposure times, with arithmetic means, standard deviations, and bounds summarized in Table 7.1-2, are to be used to calculate time spent away from contaminated environments, and in the active outdoor, inactive outdoor, and asleep indoor environments. Different distributions are to be used for the groundwater and volcanic ash exposure scenarios.

Table 7.1-2. Daily Exposure Times for Amargosa Valley Population Groups

Population Group/ Environment	Groundwater Scenario				Volcanic ash Scenario			
	Mean	SE	Min	Max	Mean	SE	Min	Max
Non-Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.2	0.2	0.8	1.8	1.2	0.2	0.8	1.8
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors[a]	12.2				12.2			
Commuters								
Away	8.0	0.5	6.8	9.4	8.3	0.6	6.9	10.0
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.4	0.2	1.0	2.0	2.0	0.2	1.5	2.6
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors[a]	6.0				5.1			
Local Outdoor Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	3.1	0.2	2.6	3.7	3.1	0.2	2.6	3.7
Inactive Outdoors	4.0	0.3	3.3	4.8	4.2	0.3	3.5	5.0
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors[a]	6.6				6.4			
Local Indoor Workers								
Away	2.0	0.4	1.2	3.3	2.0	0.4	1.2	3.3
Active Outdoors	0.3	0.1	0.1	0.7	0.3	0.1	0.1	0.7
Inactive Outdoors	1.3	0.2	0.9	1.9	1.5	0.2	1.1	2.1
Asleep Indoors	8.3	0.1	8.0	8.6	8.3	0.1	8.0	8.6
Active Indoors[a]	12.1				11.9			

NOTE: The values of exposure time are in hours per day.

[a] Calculated in the biosphere model as one minus the sum of the other four percentages; therefore a SE and distribution is not presented.

7.1.3 Breathing Rates

The summary of the breathing rates is presented in Table 7.1-3. The breathing rates are to be represented by fixed values.

Table 7.1-3. Breathing Rates (m^3/hr) by Population Group and Environment

Population Group	Active Outdoors	Inactive Outdoors	Asleep Indoors	Active Indoors
Commuters Local Outdoor Workers Local Indoor Workers Non-workers	1.57	1.08	0.39	1.08

The breathing rates for the adult Amargosa Valley population for different activity levels are summarized in Table 7.1.4.

Table 7.1-4. Breathing Rates (m^3/hr) per Level of Activity

Population Group	Sleep	Sitting	Light Exercise	Heavy Exercise
Adult, Amargosa Valley	0.39	0.47	1.38	2.86

7.1.4 Evaporative Cooler Use

The fraction of houses with evaporative coolers is to be represented by a binomial distribution with the probability of 0.738 and the batch size of 187. The resulting distribution is presented in units of households. Because the biosphere model uses the fraction of the houses with evaporative coolers rather than the number of houses, the sampled value must be divided by the batch size of 187.

The evaporative cooler use factor for the current climate is to be represented by a uniform distribution in the range from 0.32 to 0.46. For the glacial transition climate, the use factor is to be represented by a uniform distribution with a range of from 0.03 to 0.14.

7.2 DIETARY CHARACTERISTICS OF THE RECEPTOR

7.2.1 Consumption Rate of Water

Consumption of water is defined at 10 CFR 63.312 [156605] where it is stated that the RMEI drinks 2 liters of water per day, which corresponds to 730.5 liters per year.

7.2.2 Consumption Rate of Locally Produced Food

Consumption rates of locally produced food are to be represented by lognormal distributions with the means and standard deviations shown in Table 7.2-1.

Table 7.2-1. Annual Consumption Rates of Locally Produced Food by Biosphere Model Food Type

Food Type	Annual consumption rate (kg/yr)		Distribution
	Mean	SE	
Leafy vegetables	3.78	0.88	Lognormal
Other vegetables	4.73	0.67	Lognormal
Fruit	12.68	1.36	Lognormal
Grain	0.23	0.11	Lognormal
Beef	2.85	0.65	Lognormal
Poultry	0.42	0.13	Lognormal
Milk	4.66	1.68	Lognormal
Eggs	5.30	0.83	Lognormal
Fish	0.23	0.10	Lognormal

7.2.3 Inadvertent Soil Ingestion

It is recommended that the inadvertent soil ingestion for the RMEI be represented by a piece-wise cumulative probability distribution with the following characteristics: (50 mg/d, 0%), (100 mg/d, 50%), and (200 mg/d, 100%).

7.3 DOSIMETRIC PARAMETERS

7.3.1 Radionuclide Half-lives and Branching Fractions

The half-lives, decay constants and branching fractions for radionuclides included in the biosphere model are listed in Table 6.5-1.

7.3.2 Dose Conversion Factors and Dose Coefficients

DCFs for inhalation and ingestion for use in the biosphere model are shown in Table 6.5-2; dose coefficients for exposure to contaminated soil are shown in Table 6.5-3; and dose coefficients for air submersion and water immersion are shown in Table 6.5-4. These parameters are to be represented by fixed values.

The DCF for inhalation of ^{222}Rn decay products in equilibrium with radon gas is equal to 1.33×10^{-8} Sv/Bq.

7.3.3 Building Shielding Factors

Building shielding factors for primary radionuclides recommended for use in the biosphere model are listed in Table 7.3-1.

Table 7.3-1. Building Shielding Factors for Primary Radionuclides

Primary Radionuclide	Shielding Factor	Primary Radionuclide	Shielding Factor
Carbon-14 (^{14}C)	0.2		
Chlorine-36 (^{36}Cl)	0.4		
Selenium-79 (^{79}Se)	0.1		
Strontium-90 (^{90}Sr)	0.4		
Technetium-99 (^{99}Tc)	0.2		
Tin-126 (^{126}Sn)	0.4		
Iodine-129 (^{129}I)	0.1		
Cesium-135 (^{135}Cs)	0.1		
Cesium-137 (^{137}Cs)	0.4		
Thorium Series (4n)		**Neptunium Series (4n+1)**	
Plutonium-240 (^{240}Pu)	0.1	Americium-241 (^{241}Am)	0.2
Uranium-236 (^{236}U)	0.1	Neptunium-237 (^{237}Np)	0.4
Thorium-232 (^{232}Th)	0.2	Uranium-233 (^{233}U)	0.4
Radium-228 (^{228}Ra)	0.4	Thorium-229 (^{229}Th)	0.4
Uranium-232 (^{232}U)	0.3		
Thorium-228 (^{228}Th)	0.4		
Uranium Series (4n+2)		**Actinium Series (4n+3)**	
Plutonium-242 (^{242}Pu)	0.1	Americium-243 (^{243}Am)	0.4
Uranium-238 (^{238}U)	0.4	Plutonium-239 (^{239}Pu)	0.3
Plutonium-238 (^{238}Pu)	0.1	Uranium-235 (^{235}U)	0.4
Uranium-234 (^{234}U)	0.2	Protactinium-231 (^{231}Pa)	0.4
Thorium-230 (^{230}Th)	0.3	Actinium-227 (^{227}Ac)	0.4
Radium-226 (^{226}Ra)	0.4		
Lead-210 (^{210}Pb)	0.4		

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

151548 Anspaugh, L.R.; Shinn, J.H.; Phelps, P.L.; and Kennedy, N.C. 1975. "Resuspension and Redistribution of Plutonium in Soils." *Health Physics*, 29, (4), 571-582. New York, New York: Pergamon Press. TIC: 248619.

147076 Bevington, P.R. and Robinson, D.K. 1992. *Data Reduction and Error Analysis for the Physical Sciences*. 2nd Edition. New York, New York: McGraw-Hill. TIC: 243514.

156016 BSC (Bechtel SAIC Company) 2001. *Calculation: Consumption Rates of Locally Produced Food in Nye and Lincoln Counties*. CAL-MGR-EV-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010628.0242.

160130 BSC (Bechtel SAIC Company) 2001. *Characterize Eruptive Processes at Yucca Mountain, Nevada*. ANL-MGR-GS-000002 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020327.0498.

160255 BSC (Bechtel SAIC Company) 2001. *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)*. ANL-MGR-MD-000005 REV 01 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020124.0203.

157876 BSC (Bechtel SAIC Company) 2001. *Igneous Consequence Modeling for the TSPA-SR*. ANL-WIS-MD-000017 REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011107.0005.

160059 BSC (Bechtel SAIC Company) 2002. *Radionuclide Screening*. ANL-WIS-MD-000006 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020923.0177.

160146 BSC (Bechtel SAIC Company) 2002. *Total System Performance Assessment-License Application Methods and Approach.* TDR-WIS-PA-000006 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20020923.0175.

160699 BSC (Bechtel SAIC Company) 2003. *Biosphere Model Report*. MDL-MGR-MD-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20030124.0246. TBV-5081

163602 BSC (Bechtel SAIC Company) 2003. *Technical Work Plan for: Biosphere Modeling and Expert Support.* TWP-NBS-MD-000004 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20030604.0001.

111961 Bulmer, M.G. 1979. *Principles of Statistics*. 3rd Edition. New York, New York: Dover. TIC: 245835.

160177 Bureau of the Census. 2001. *Statistical Abstract of the United States: 2001*. 121st Edition. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census. TIC: 252180.

159728 Bureau of the Census. 2002. "2000 Summary File 3 (SF 3) Sample Data, Amargosa Valley CCD, Nye County, Nevada." Washington, D.C.: U.S. Department of Commerce, Bureau of the Census. Accessed August 28, 2002. TIC: 253098. http://factfinder.census.gov/servlet/DTTable?_ts=48597952130

160179 Bureau of the Census. 2002. "Accuracy of the Data." Chapter 8 of *2000 Census of Population and Housing, Summary File 3, Technical Documentation*. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census. TIC: 253100.

161770 Canori, G.F. and Leitner, M.M. 2003. *Project Requirements Document*. TER-MGR-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20030404.0003.

160095 Castor, S.B. 2001. "Industrial Minerals." *The Nevada Mineral Industry 2000*. Meeuwig, D., ed. Special Publication MI-2000. 39-42. Reno, Nevada: Nevada Bureau of Mines and Geology. TIC: 252603.

101090 CRWMS M&O 1997. *Yucca Mountain Site Characterization Project Summary of Socioeconomic Data Analyses Conducted in Support of the Radiological Monitoring Program First Quarter 1996 to First Quarter 1997*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971117.0460.

102877 CRWMS M&O 1999. *Environmental Baseline File for Meteorology and Air Quality*. B00000000-01717-5705-00126 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990302.0186.

153246 CRWMS M&O 2000. *Total System Performance Assessment for the Site Recommendation*. TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

152536 CRWMS M&O 2001. *Disruptive Event Biosphere Dose Conversion Factor Analysis*. ANL-MGR-MD-000003 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010125.0233.

160096 Davis, D.A. 2001. "Directory of Mining and Milling Operations." *The Nevada Mineral Industry 2000*. Nevada Bureau of Mines and Geology Special Publication MI-2000. 55-61. Reno, Nevada: University of Nevada, Reno, Mackay School of Mines. TIC: 252603.

100332 DOE (U.S. Department of Energy) 1997. *The 1997 "Biosphere" Food Consumption Survey Summary Findings and Technical Documentation*. Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981021.0301.

153849 DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report*. DOE/RW-0539. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.

159476 Dorrian, M.-D. 1997. "Particle Size Distributions of Radioactive Aerosols in the Environment." *Radiation Protection Dosimetry*, 69, (2), 117-132. Ashford, Kent, England: Nuclear Technology Publishing. TIC: 252686.

160175 Driesner, D. and Coyner, A. 2001. *Major Mines of Nevada 2000, Mineral Industries in Nevada's Economy*. Nevada Bureau of Mines and Geology Special Publication P-12. Reno, Nevada: University of Nevada Reno, Mackay School of Mines. TIC: 252602.

162466 Duan, N. 1982. "Models for Human Exposure to Air Pollution." *Environment International*, 8, 305-309. [New York, New York]: Pergamon Press. TIC: 250558.

107684 Eckerman, K.F. and Ryman, J.C. 1993. *External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance*. EPA 402-R-93-081. Federal Guidance Report No. 12. Washington, D.C.: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. TIC: 225472.

101069 Eckerman, K.F.; Wolbarst, A.B.; and Richardson, A.C.B. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. EPA 520/1-88-020. Federal Guidance Report No. 11. Washington, D.C.: U.S. Environmental Protection Agency. ACC: MOL.20010726.0072.

160121 EPA (U.S. Environmental Protection Agency) 1996. *Air Quality Criteria for Particulate Matter*. EPA/600/P-95/001. Three volumes. Washington, D.C.: U.S. Environmental Protection Agency. TIC: 250648.

116135 EPA (U.S. Environmental Protection Agency) 1997. *Activity Factors*. Volume III of *Exposure Factors Handbook*. EPA/600/P-95/002Fc. Washington, D.C.: U.S. Environmental Protection Agency. TIC: 241062.

103038 EPA (U.S. Environmental Protection Agency) 1997. *General Factors*. Volume I of *Exposure Factors Handbook*. EPA/600/P-95/002Fa. Washington, D.C.: U.S. Environmental Protection Agency. TIC: 241060.

146973 Golder Associates. 2000. GoldSim, *Graphical Simulation Environment, User's Guide*. Version 6.02. Manual Draft #4 (March 17, 2000). Redmond, Washington: Golder Associates. TIC: 247347.

163051 ICRP (International Commission on Radiological Protection) 1981. *Limits for Inhalation of Radon Daughters by Workers*. Volume 6, No. 1 of *Annals of the ICRP*, ICRP Publication 32. New York, New York: Pergamon Press. Copyright Requested

163147 ICRP (International Commission on Radiological Protection) 1982. *Limits for Intakes of Radionuclides by Workers.* Volume 7, No. 1-3 of *Annals of the ICRP.* ICRP Publication 30, Supplement A to Part 3. Reprinted 1990. New York, New York: Pergamon Press. TIC: 4944.

.

101075 ICRP (International Commission on Radiological Protection) 1977. *Recommendations of the International Commission on Radiological Protection*. Volume 1, No. 3 of *Annals of the ICRP*. ICRP Publication 26. Reprinted 1982. New York, New York: Pergamon Press. TIC: 221568.

101076 ICRP (International Commission on Radiological Protection) 1978. "Limits for Intakes of Radionuclides by Workers." *Annals of the ICRP*. ICRP Publication 30 Supplement to Part 1. New York, New York: Pergamon Press. TIC: 221575.

110386 ICRP (International Commission on Radiological Protection) 1979. *Limits for Intakes of Radionuclides by Workers*. Volume 2, No. 3/4 of *Annals of the ICRP*. Sowby, F.D., ed. ICRP Publication 30 Part 1. New York, New York: Pergamon Press. TIC: 4939.

110351 ICRP (International Commission on Radiological Protection) 1980. *Limits for Intakes of Radionuclides by Workers*. Volume 4, No. 3/4 of *Annals of the ICRP*. Sowby, F.D., ed. ICRP Publication 30 Part 2. Reprinted 1990. Elmsford, New York: Pergamon Press. TIC: 4941.

153056 ICRP (International Commission on Radiological Protection) 1981. *Limits for Intakes of Radionuclides by Workers*. Volume 5, No. 1-6 of *Annals of the ICRP*. ICRP Publication 30, Supplement to Part 2. New York, New York: Pergamon Press. TIC: 4942.

110352 ICRP (International Commission on Radiological Protection) 1981. *Limits for Intakes of Radionuclides by Workers*. Volume 6, No. 2/3 of *Annals of the ICRP*. Sowby, F.D., ed. ICRP Publication 30 Part 3, Including Addendum to Parts 1 and 2. New York, New York: Pergamon Press. TIC: 4943.

153057 ICRP (International Commission on Radiological Protection) 1982. *Limits for Intakes of Radionuclides by Workers*. Volume 8, No. 1-3 of *Annals of the ICRP*.

ICRP Publication 30, Supplement B to Part 3 Including Addendum to the Supplements of Parts 1 and 2. New York, New York: Pergamon Press. TIC: 4945.

101836 ICRP (International Commission on Radiological Protection) 1991. "1990 Recommendations of the International Commission on Radiological Protection." Volume 21, No. 1-3 of *Annals of the ICRP*. ICRP Publication 60. New York, New York: Pergamon Press. TIC: 235864.

153705 ICRP (International Commission on Radiological Protection) 1994. *Human Respiratory Tract Model for Radiological Protection*. Volume 24, Nos. 1-3 of *Annals of the ICRP*. Smith, H., ed. ICRP Publication 66. [New York, New York]: Pergamon. TIC: 249223.

152446 ICRP (International Commission on Radiological Protection) 1996. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients*. Volume 26, No. 1 of *Annals of the ICRP*. Smith, H., ed. ICRP Publication 72. New York, New York: Pergamon Press. TIC: 235870.

100987 Jarzemba, M.S.; LaPlante, P.A.; and Poor, K.J. 1997. *ASHPLUME Version 1.0—A Code for Contaminated Ash Dispersal and Deposition, Technical Description and User's Guide*. CNWRA 97-004, Rev. 1. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. ACC: MOL.20010727.0162.

160094 Klepeis, N.E. 1999. "An Introduction to the Indirect Exposure Assessment Approach: Modeling Human Exposure Using Microenvironmental Measurements and the Recent National Human Activity Pattern Survey." *Environmental Health Perspectives*, 107, (Supplement 2), 365-374. [Research Park Triangle, North Carolina: National Institute of Environmental Health Sciences, National Institutes of Health]. TIC: 250567.

159299 Klepeis, N.E.; Tsang, A.M.; and Behar, J.V. 1996. *Analysis of the National Human Activity Pattern Survey (NHAPS) Respondents from a Standpoint of Exposure Assessment, Percentage of Time Spent, Duration, and Frequency of Occurrence for Selected Microenvironments by Gender, Age, Time-of-day, Day-of-week, Season, and U.S. Census Region, Final Report*. EPA/600/R-96/074. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development. TIC: 252656.

161052 Knoll, G.F. 1989. *Radiation Detection and Measurement*. 2nd Edition. New York, New York: John Wiley & Sons. TIC: 233703.

101079 LaPlante, P.A. and Poor, K. 1997. *Information and Analyses to Support Selection of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios*. CNWRA 97-009. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. ACC: MOL.20010721.0035.

103178 Lide, D.R. and Frederikse, H.P.R., eds. 1997. *CRC Handbook of Chemistry and Physics*. 78th Edition. Boca Raton, Florida: CRC Press. TIC: 243741.

162465 Mage, D.T. 1985. "Concepts of Human Exposure Assessment for Airborne Particulate Matter." *Environment International*, 11, 407-412. [New York, New York]: Pergamon Press. TIC: 250582.

161091 NCDC (National Climatic Data Center) [n.d.]. *Hourly United States Weather Observations 1990-1995.* [Washington, D.C.]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration. TIC: 253573.

160260 NCRP (National Council on Radiation Protection and Measurements) 1997. *Deposition, Retention and Dosimetry of Inhaled Radioactive Substances.* NCRP Report No. 125. Bethesda, Maryland: National Council on Radiation Protection and Measurements. TIC: 232976.

160160 NCRP (National Council on Radiation Protection and Measurements) 1998. *Evaluating the Reliability of Biokinetic and Dosimetric Models and Parameters Used to Assess Individual Doses for Risk Assessment Purposes.* NCRP Commentary No. 15. Bethesda, Maryland: National Council on Radiation Protection and Measurements. TIC: 252922.

155894 NCRP (National Council on Radiation Protection and Measurements) 1999. *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies.* NCRP Report No. 129. Bethesda, Maryland: National Council on Radiation Protection and Measurements. TIC: 250396.

160176 Nevada Department of Minerals; Nevada Bureau of Mines and Geology; and Mackay School of Mines. 1991. *Major Mines of Nevada, 1990.* Nevada Bureau of Mines and Geology Special Publication 11. Reno, Nevada: University of Nevada Reno, Mackay School of Mines. TIC: 222736.

160116 Nicholson, K.W. 1988. "A Review of Particle Resuspension." *Atmospheric Environment, 22,* (12), 2639-2651. New York, New York: Pergamon Press. TIC: 252279.

150855 Nieuwenhuijsen, M.J.; Kruize, H.; and Schenker, M.B. 1998. "Exposure to Dust and Its Particle Size Distribution in California Agriculture." *American Industrial Hygiene Association Journal, 59,* 34-38. [Fairfax, Virginia]: American Industrial Hygiene Association. TIC: 248134.

163018 NRC (U.S. Nuclear Regulatory Commission) 2003. *Use of the Effective Dose Equivalent in Place of the Deep Dose Equivalent in Dose Assessments.* RIS 2003-04. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 254200.

162418 NRC (U.S. Nuclear Regulatory Commission) 2003. *Yucca Mountain Review Plan, Information Only.* NUREG-1804, Draft Final Revision 2. Washington, D.C.: U.S.

Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 254002.

157704 NRC (U.S. Nuclear Regulatory Commission) 2000. *A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities, Recommendations of NRC's Performance Assessment Working Group.* NUREG-1573. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 252174.

159577 Pinnick, R.G.; Fernandez, G.; Hinds, B.D.; Bruce, C.W.; Schaefer, R.W.; and Pendleton, J.D. 1985. "Dust Generated by Vehicular Traffic on Unpaved Roadways: Sizes and Infrared Extinction Characteristics." *Aerosol Science and Technology, 4,* (1), 99-121. New York, New York: Elsevier. TIC: 252364.

160312 Pinnick, R.G.; Fernandez, G.; Martinez-Andazola, E.; Hinds, B.D.; Hansen, A.D.A.; and Fuller, K. 1993. "Aerosol in the Arid Southwestern United States: Measurements of Mass Loading, Volatility, Size Distribution, Absorption Characteristics, Black Carbon Content, and Vertical Structure to 7 km Above Sea Level." *Journal of Geophysical Research, 98,* (D2), 2651-2666. Washington, D.C.: American Geophysical Union. TIC: 252365.

154597 Reamer, C.W. and Williams, D.R. 2000. Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Igneous Activity. Meeting held August 29-31, 2000, Las Vegas, Nevada, with attachments. [Washington, D.C.]: U.S. Nuclear Regulatory Commission. ACC: MOL.20001101.0105; through; MOL.20001101.0128.

107744 Rittmann, P.D. 1993. *Verification Tests for the July 1993 Revision to the GENII Radionuclide and Dose Increment Libraries.* WHC-SD-WM-TI-596. Richland, Washington: Westinghouse Hanford Company. TIC: 233965.

160115 Shinn, J.H. [1992]. "Enhancement Factors for Resuspended Aerosol Radioactivity: Effects of Topsoil Disturbance." *[Proceedings of the Fifth International Conference on Precipitation Scavenging and Atmosphere-Surface Exchange Processes, Richland, Washington, 15-19 July 1991].* 1183-1193. [Washington, D.C.: Hemisphere]. TIC: 252292.

160098 Simon, S.L. 1998. "Soil Ingestion by Humans: A Review of History, Data, and Etiology with Application to Risk Assessment of Radioactively Contaminated Soil." *Health Physics, 74,* (6), 647-672. Baltimore, Maryland: Williams & Wilkins. TIC: 253001.

160251 Stanek, E.J., III.; Calabrese, E.J.; Barnes, R.; and Pekow, P. 1997. "Soil Ingestion in Adults—Results of a Second Pilot Study." *Ecotoxicology and Environmental Safety, 36,* (3), 249-257. [San Diego, California]: Academic Press. TIC: 252381.

110928 State of Nevada 1999. *Nevada State Water Plan, Part 2 – Water Use and Forecasts.* Carson City, Nevada: State of Nevada, Department of Conservation and Natural Resources. TIC: 244812.

147766 Thiel Engineering Consultants 1999. *Data Assessment & Water Rights/Resource Analysis of: Hydrographic Region #14 Death Valley Basin.* Reno, Nevada: Thiel Engineering Consultants. ACC: MOL.19990218.0214.

158644 UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) 2000. *Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes.* Two volumes. New York, New York: United Nations. TIC: 249863.

154158 USDA (U.S. Department of Agriculture) 2000. *Food and Nutrient Intakes by Individuals in the United States, 1994-1996.* Nationwide Food Surveys Report No. 96-3. Two volumes. [Washington, D.C.: U.S. Department of Agriculture]. TIC: 249498.

158378 USGS (U.S. Geological Survey) 2001. *Future Climate Analysis.* ANL-NBS-GS-000008 REV 00 ICN 01. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20011107.0004.

159497 Watt, J.R. and Brown, W.K. 1997. *Evaporative Air Conditioning Handbook.* 3rd Edition. Lilburn, Georgia: Fairmont Press. TIC: 252688.

154817 YMP (Yucca Mountain Site Characterization Project) 2001. *Q-List.* YMP/90-55Q, Rev. 7. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20010409.0366.

159465 Yu, C.; Zielen, A.J.; Cheng, J.-J.; LePoire, D.J.; Gnanapragasam, E.; Kamboj, S.; Arnish, J.; Wallo, A., III.; Williams, W.A.; and Peterson, H. 2001. *User's Manual for RESRAD Version 6.* ANL/EAD-4. Argonne, Illinois: Argonne National Laboratory. TIC: 252702.

8.2 DATA TRACKING NUMBERS CITED

160708 LA0107GV831811.001. Parameters for Igneous Consequences Analysis. Submittal date: 07/11/2001.

154976 MO0010SPANYE00.001. Cleaned Nye County Food Consumption Frequency Survey. Submittal date: 10/10/2000.

160256 MO0106SPAECL02.016. Estimated Consumption of Locally Produced Food for 1,499 Respondents in Nye and Lincoln Counties. Submittal date: 06/19/2001.

162452 MO0303SEPFEPS2.000. LA FEP List. Submittal date: 03/26/2003.

135880 MO98METDATA110.000. Validated Meteorological Data, October - December, 1997. Submittal date: 01/29/1998.

150063 MO9903VALMM961.000. Validated Meteorological Monitoring Data, January - March 1996. Submittal date: 03/29/1999.

150132 MO9903VALMM962.000. Validated Meteorological Monitoring Data, April - June 1996. Submittal date: 03/29/1999.

150130 MO9903VALMM963.000. Validated Meteorological Monitoring Data, July - September 1996. Submittal date: 03/29/1999.

150131 MO9903VALMM964.000. Validated Meteorological Monitoring Data, October - December 1996. Submittal date: 03/29/1999.

150133 MO9905VMMDAJ94.000. Validated Meteorological Monitoring Data, April - June 1994. Submittal date: 05/29/1999.

150068 MO9905VMMDJM94.000. Validated Meteorological Monitoring Data, January - March 1994. Submittal date: 05/29/1999.

150134 MO9905VMMDJS94.000. Validated Meteorological Monitoring Data, July - September 1994. Submittal date: 05/24/1999.

150137 MO9905VMMDOD94.000. Validated Meteorological Monitoring Data, October - December 1994. Submittal date: 05/29/1999.

156272 SN0109T0502900.005. Updated Igneous Consequence Data for Total System Performance Assessment-Site Recommendation (TSPA-SR) Revised to Support No-Backfill Design Change. Submittal date: 09/28/2001.

161051 TM000000000001.065. Validated Meteorological Data, January - March 1995. Submittal date: 04/11/1995.

161050 TM000000000001.068. Validated Meteorological Data, April - June 1995. Submittal date: 10/04/1995.

161049 TM000000000001.071. Validated Meteorological Data, July - September 1995. Submittal date: 11/09/1995.

152925 TM000000000001.077. Validated Meteorological Data, October - December 1995. Submittal date: 02/13/1996.

135874 TM000000000001.100. Validated Meteorological Data, January - March 1997. Submittal date: 04/18/1997.

135876 TM000000000001.104. Validated Meteorological Data, April - June 1997. Submittal date: 07/21/1997.

135878 TM000000000001.107. Validated Meteorological Data, July - September 1997. Submittal date: 10/22/1997.

8.3 CODES, STANDARDS, AND REGULATIONS

104787 10 CFR 20. Energy: Standards for Protection Against Radiation. Readily available.

156605 10 CFR 63. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

155238 40 CFR 197. 2001. Protection of Environment: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Readily available

156671 66 FR 55732. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, NV. Final Rule 10 CFR Part 63. Readily available.

8.4 CITED PROCEDURES

159604 AP-2.27Q, Rev. 0, ICN 0. *Planning for Science Activities*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020701.0184.

8.5 ANALYSIS OUTPUT

MO0306SPACRBSM.001. Characteristics of the Receptor for the Biosphere Model. Submittal date: 06/11/2003.

ATTACHMENT I

CALCULATION OF CONSUMPTION RATES OF LOCALLY PRODUCED FOOD

CALCULATION OF CONSUMPTION RATES OF LOCALLY PRODUCED FOOD

This attachment explains the spreadsheet calculations of consumption rates of locally produced food. The calculations were done using standard function of Microsoft Excel 97 SR-2. The calculation method is described in Section 6.4.2. The calculations are done in the Excel workbook named *Consumption rates with uncertainties.xls*. The file is in Attachment III. The workbook consists of three worksheets: *Consumption rates, Survey data*, and *Consumption rates formulas*.

In the workbook **Survey data**, the effective number of days per year (EDPY) that an individual consumed locally produced food from a given food group is calculated separately for males and females, together with the standard deviation, count, and the SE of the mean. These calculations are done for 195 individuals residing in the Amargosa Valley that participated in the regional survey and for 12 food groups that were included in the survey. Equation 6.4-1 was used to calculate EDPY as follows:

$$EDPY_{i,j} = MPY_{i,j} \frac{365.25\,d}{12\,mo} DPW_{i,j} \frac{1\,wk}{7\,d} Q_{i,j}$$

The values of *MPY*, *DPW*, and *Q* for individual food groups are taken from the results of the regional survey residing in the *Cleaned Nye County Food Consumption Frequency Survey* data set, DTN: MO0010SPANYE00.001 [154976]. The individual responses are coded in the data set (and the same coding is maintained in the worksheet) as:

Q3A2-A, Q3A3-A, Q3A4-A for leafy vegetables
Q3B2-A, Q3B3-A, Q3B4-A for root (other) vegetables
Q3C2-A, Q3C3-A, Q3C4-A for grain
Q3D2-A, Q3D3-A, Q3D4-A for fruit
Q3E2-A, Q3E3-A, Q3E4-A for poultry
Q3F2-A, Q3F3-A, Q3F4-A for beef
Q3G2-A, Q3G3-A, Q3G4-A for pork
Q3H2-A, Q3D3-A, Q3D4-A for game
Q3I2-A, Q3I3-A, Q3I4-A for fish
Q3J2-A, Q3J3-A, Q3J4-A for milk
Q3K2-A, Q3K3-A, Q3K4-A for eggs
Q3M2-A, Q3M3-A, Q3M4-A for tomatoes

For every food group and gender, the mean value of EDPY is calculated using the AVERAGE function of Excel for the defined range of EDPY values. The standard deviation of EDPY is calculated using STDEV function of Excel for the defined range of cells. The count corresponds to the number of valid numerical EDPY results ("DK or Refuse" and "Invalid" are not included) for a given food group and gender and is calculated using the COUNT Excel function. The SE of the mean EDPY is calculated by dividing the standard deviation by the square root of the count.

The mean, standard deviation, count, SE of the mean are carried to the **Consumption rates** worksheet. The mean and the SE are subsequently used to calculate the consumption rates, while the standard deviation and the count are only shown to provide the convenient summary of values.

The image of the **Consumption rates** spreadsheet is shown in Figure I-1. The spreadsheet content is as follows:

Column	Description
A	Identification of food groups used in the regional survey
B	Gender designation (the value of average daily intake, *ADI*, of a specific food is gender-specific)
C	Mean value of *ADI* by food group and gender from the USDA Survey of Food Intake (USDA 2000 [154158])
D	SE of the mean *ADI*s by food group and gender from the USDA Survey of Food Intake (USDA 2000 [154158])
E	Mean value of the fraction of people consuming, *FPC*, food from a given food group by food group and gender from the USDA Survey of Food Intake (USDA 2000 [154158])
F	SE of the mean value of *FPC* food from a given food group by food group and gender from the USDA Survey of Food Intake (USDA 2000 [154158])
G	not used
H	Mean value of the *CADI* by food group and gender calculated as the ratio of *ADI* (column C) and *FPC* (column E)
I	SE of the mean *CADI* calculated using the following formula (Eq. 6.4-6):

$$SEM_{CADI_i} = \sqrt{\left(\frac{SEM_{ADI_i}}{FPC_i}\right)^2 + \left(\frac{ADI_i\, SEM_{FPC\,i}}{(FPC_i)^2}\right)^2}$$

where: SEM_{ADI} is taken from column D
FPC is taken from column E
ADI is taken from column C
SEM_{FPC} is taken form column F

Column	Description
J	not used
K	Mean value of *EDPY* for the given food group and gender, which is calculated from the survey data in the **Survey data** worksheet as described above.
L	Standard deviation of *EDPY* for the given food group and gender, which is calculated from the survey data in the **Survey data** worksheet as described above.
M	Number of valid *EDPY* cells (count) for the given food group and gender, which is calculated from the survey data in the **Survey data** worksheet as described above.

Column	Description
N	SE of the mean *EDPY* for the given food group and gender, which is calculated from the survey data in the **Survey data** worksheet as described above.
O	Percent of the Amargosa Valley population for males (*PM*) and females (*PF*) from the 2000 Census data (Bureau of the Census (2002 [159728]) for age groups 18 and over.
P	not used
Q	Mean consumption rate of locally produced food calculated using Equation 6.4-2: $U_i = \overline{EDPY}_{i,m}\ CADI_{i,m}\ PM + \overline{EDPY}_{i,f}\ CADI_{i,f}\ PF$ where: $EDPY_m$ and $EDPY_f$ are taken from column K; $CADI_m$ and $CADI_f$ are taken from column H; *PM* and *PF* are taken from column O
R	Partial results for calculation of SE of the mean consumption rate of locally produced food (Equation 6.4-4), representing the "male" and "female" contribution to the SE, i.e., the terms that appear in the parentheses before they are multiplied by $(PM)^2$ and $(PF)^2$ respectively. $SEM_{U_i}^{\ 2} = \left(\left(CADI_{i,m}\right)^2 \left(SEM_{\overline{EDPY}_{i,m}}\right)^2 + \left(\overline{EDPY}_{i,m}\right)^2 \left(SEM_{CADI_{i,m}}\right)^2\right)(PM)^2 + \left(\left(CADI_{i,f}\right)^2 \left(SEM_{\overline{EDPY}_{i,f}}\right)^2 + \left(\overline{EDPY}_{i,f}\right)^2 \left(SEM_{CADI_{i,f}}\right)^2\right)(PF)^2$ where: $CADI_m$ and $CADI_f$ are taken from column H; $EDPY_m$ and $EDPY_f$ are taken from column K; $SEM_{CADI\,m}$ and $SEM_{CADI\,f}$ are taken from column I; $SEM_{EDPY\,m}$ and $SEM_{EDPY\,f}$ are taken from column N
S	In this column calculation of the SE of the mean is completed by multiplying the values from column R for males and females by $(PM)^2$ an $(PF)^2$ (column O), respectively, adding the results, taking the square root of the sum and dividing it by 1000 to convert the value from grams to kilograms.
T	not used
U	Mean consumption rate of locally produced food for the biosphere model food types (the regional survey food groups were combines as explained in Section 6.4.2). The values are calculated by either copying the content of cells in column R, if no grouping is involved, or adding the values in column R if the biosphere model food types include more than one regional survey food group.
V	SE of the mean consumption rate for the biosphere model food types. It is calculated by either copying the content of cells in column S, if no grouping is involved, or taking the square root of the squared values in column S if the biosphere model food types include more than one regional survey food group.
W	not used

Column	**Description**
X,Y,Z, AA	These columns are used to calculate GM and standard deviation of the lognormal distribution of the mean consumption rate for the biosphere model food types. These parameters are given for comparison only and are not used in the biosphere model. The values of geometric mean and standard deviation and the intermediate parameters ζ and λ are calculated using Equations 6.4-7 through 6.4-9. These columns are not shown in Figure I-1.

Figures I-2 and II-3 show the formulas for the **Consumption rates** worksheet shown in Figure I-1.

Calculation of Food Consumption Rates

for the Characteristics of the Receptor for the Biosphere Model

ANL-MGR-MD-000005 REV 02

Food Group		ADI		FPC		CADI		EDPY					Consumption Rate, U Survey Food Groups			Consumption Rate Biosphere Model Food Type	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	Stdev	Count	SEM	% popul.	Mean		SEM	Mean	SEM
Leafy Vegetables	M	13	3	0.103	0.015	126.2	34.4	30.70	60.15	70.00	7.19	0.522	3.78	1.941E+06	0.88	3.78	0.88
	F	16	3	0.133	0.014	120.3	25.9	30.53	60.36	108.00	5.81	0.478		1.112E+06			
Other vegetables	M	66	6	0.417	0.021	158.3	16.4	30.76	49.61	70.00	5.93	0.522	4.73	1.137E+06	0.67	4.73	0.67
	F	43	3	0.35	0.016	122.9	10.2	37.22	58.67	107.00	5.67	0.478		6.311E+05			
Fruit	M	194	12	0.535	0.022	362.6	26.9	22.16	38.03	70.00	4.55	0.522	9.35	3.074E+06	1.28	12.68	1.36
	F	181	15	0.603	0.025	300.2	27.8	35.91	55.12	111.00	5.23	0.478		3.464E+06			
Tomatoes	M	43	2	0.447	0.01	96.2	5.0	33.25	47.35	53.00	6.50	0.522	3.33	4.187E+05	0.48		
	F	27	2	0.398	0.022	67.8	6.3	51.17	89.31	87.00	9.58	0.478		5.249E+05			
Grain	M	382	18	0.973	0.007	392.6	18.7	0.00	0.00	71.00	0.00	0.522	0.23	0.000E+00	0.11	0.23	0.11
	F	266	12	0.968	0.005	274.8	12.5	1.76	8.85	106.00	0.86	0.478		5.630E+04			
Beef	M	37	3	0.258	0.024	143.4	17.7	19.34	61.11	71.00	7.25	0.522	2.18	1.199E+06	0.62	2.85	0.65
	F	17	2	0.194	0.014	87.6	12.1	17.59	54.34	109.00	5.20	0.478		2.532E+05			
Pork	M	12	2	0.169	0.012	71.0	12.9	7.63	31.11	71.00	3.69	0.522	0.53	7.836E+04	0.17		
	F	6	1	0.132	0.014	45.5	9.0	11.59	37.30	112.00	3.52	0.478		3.649E+04			
Wild Game	M	2	1	0.012	0.007	166.7	128.0	0.72	3.33	71.00	0.40	0.522	0.13	1.284E+04	0.10		
	F	1	1	0.01	0.004	100.0	107.7	1.50	7.76	112.00	0.73	0.478		3.163E+04			
Poultry	M	29	3	0.215	0.012	134.9	15.9	4.31	13.89	70.00	1.66	0.522	0.42	5.479E+04	0.13	0.42	0.13
	F	17	2	0.207	0.018	82.1	12.0	2.90	11.28	112.00	1.07	0.478		8.879E+03			
Milk	M	193	9	0.496	0.02	389.1	24.0	13.03	59.93	69.00	7.21	0.522	4.66	7.978E+06	1.68	4.66	1.68
	F	155	10	0.513	0.025	302.1	24.4	13.97	56.27	108.00	5.41	0.478		2.793E+06			
Eggs	M	29	3	0.239	0.019	121.3	15.8	34.82	69.48	70.00	8.30	0.522	5.30	1.319E+06	0.83	5.30	0.83
	F	18	2	0.189	0.012	95.2	12.2	67.86	94.66	111.00	8.98	0.478		1.416E+06			
Fish	M	12	2	0.093	0.009	129.0	24.9	1.72	8.87	70.00	1.06	0.522	0.23	2.055E+04	0.10	0.23	0.10
	F	9	2	0.078	0.012	115.4	31.2	2.13	9.81	112.00	0.93	0.478		1.583E+04			

CADI = contingent average daily intake
EDPY = equivalent days per year
SEM = standard error of the mean

% population was taken from 2000 Census

$$SEM_{CADI_i} = \sqrt{\left(\frac{SEM_{ADI_i}}{FPC_i}\right)^2 + \left(\frac{ADI_i \; SEM_{FPC_i}}{(FPC_i)^2}\right)^2}$$

$$SEM_{U_i}{}^2 = \left(\left(CADI_{i,m}\right)^2 \left(SEM_{\overline{EDPY}_{i,m}}\right)^2 + \left(\overline{EDPY}_{i,m}\right)^2 \left(SEM_{CADI_{i,m}}\right)^2\right)(PM)^2 + \left(\left(CADI_{i,f}\right)^2 \left(SEM_{\overline{EDPY}_{i,f}}\right)^2 + \left(\overline{EDPY}_{i,f}\right)^2 \left(SEM_{CADI_{i,f}}\right)^2\right)(PF)^2$$

Figure I-1. Image of the *Consumption rates* Worksheet of the *Consumption rates with uncertainties* Workbook.

Microsoft Excel - Consumption rates with uncertainties

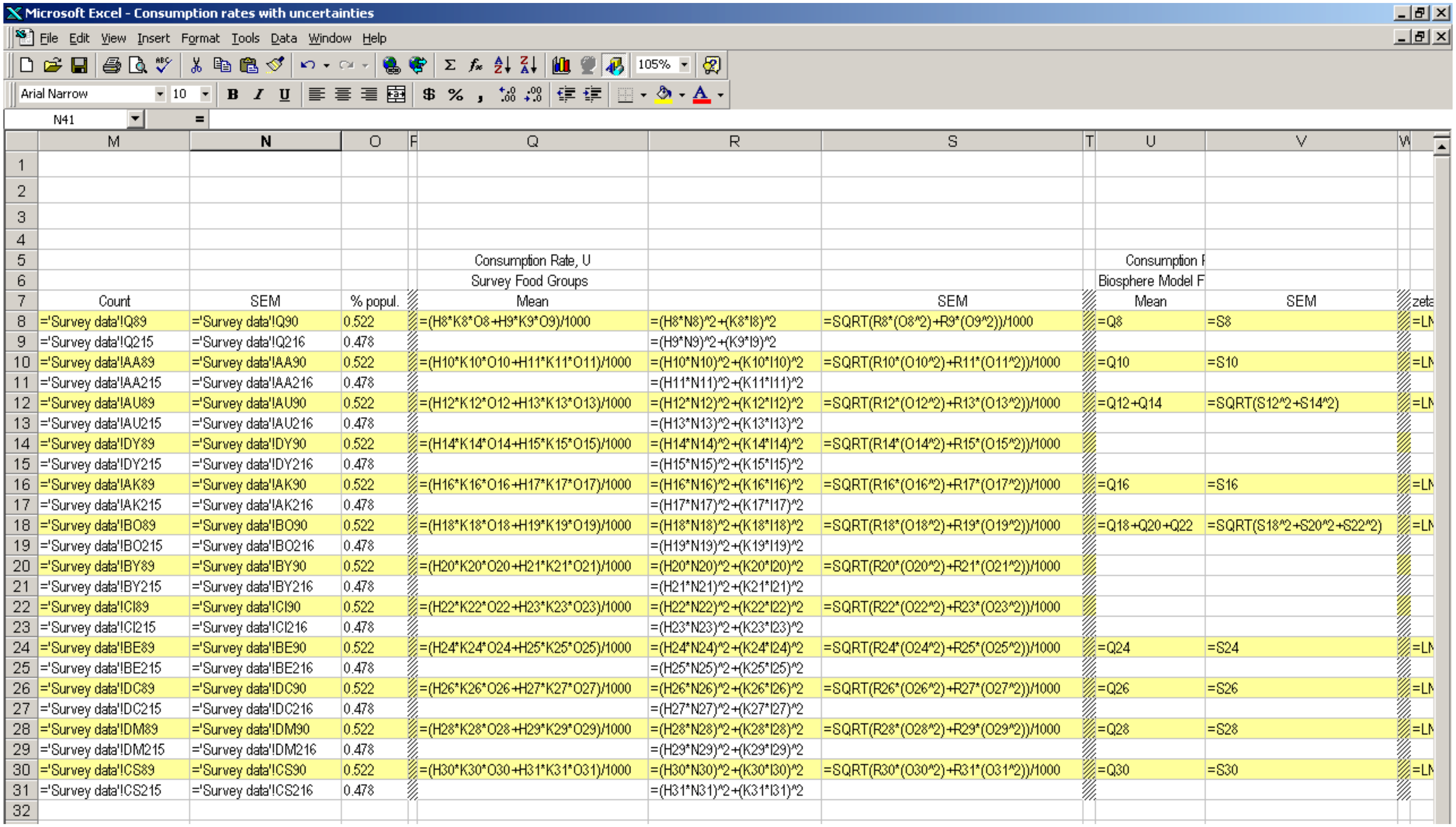
File Edit View Insert Format Tools Data Window Help

Arial Narrow 10 105%

N41 =

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Calculation of F															
2	for the Characte															
3	ANL-MGR-MD-(															
4																
5																
6	**Food Group**		<---------		<---------			<----------C.			<---------------------------					
7			Mean	SEM	Mean	SEM		Mean	SEM		Mean	Stdev	Count	SEM	% popul.	
8	Leafy Vegetables	M	13	3	0.103	0.015		=C8/E8	=SQRT((D8/E8)^2+(C8*F8/(E8^2))^2)		='Survey data'!Q87	='Survey data'!Q88	='Survey data'!Q89	='Survey data'!Q90	0.522	=(H8
9		F	16	3	0.133	0.014		=C9/E9	=SQRT((D9/E9)^2+(C9*F9/(E9^2))^2)		='Survey data'!Q213	='Survey data'!Q214	='Survey data'!Q215	='Survey data'!Q216	0.478	
10	Other vegetables	M	66	6	0.417	0.021		=C10/E10	=SQRT((D10/E10)^2+(C10*F10/(E10^2))^2)		='Survey data'!AA87	='Survey data'!AA88	='Survey data'!AA89	='Survey data'!AA90	0.522	=(H1
11		F	43	3	0.35	0.016		=C11/E11	=SQRT((D11/E11)^2+(C11*F11/(E11^2))^2)		='Survey data'!AA213	='Survey data'!AA214	='Survey data'!AA215	='Survey data'!AA216	0.478	
12	Fruit	M	194	12	0.535	0.022		=C12/E12	=SQRT((D12/E12)^2+(C12*F12/(E12^2))^2)		='Survey data'!AU87	='Survey data'!AU88	='Survey data'!AU89	='Survey data'!AU90	0.522	=(H1
13		F	181	15	0.603	0.025		=C13/E13	=SQRT((D13/E13)^2+(C13*F13/(E13^2))^2)		='Survey data'!AU213	='Survey data'!AU214	='Survey data'!AU215	='Survey data'!AU216	0.478	
14	Tomatoes	M	43	2	0.447	0.01		=C14/E14	=SQRT((D14/E14)^2+(C14*F14/(E14^2))^2)		='Survey data'!DY87	='Survey data'!DY88	='Survey data'!DY89	='Survey data'!DY90	0.522	=(H1
15		F	27	2	0.398	0.022		=C15/E15	=SQRT((D15/E15)^2+(C15*F15/(E15^2))^2)		='Survey data'!DY213	='Survey data'!DY214	='Survey data'!DY215	='Survey data'!DY216	0.478	
16	Grain	M	382	18	0.973	0.007		=C16/E16	=SQRT((D16/E16)^2+(C16*F16/(E16^2))^2)		='Survey data'!AK87	='Survey data'!AK88	='Survey data'!AK89	='Survey data'!AK90	0.522	=(H1
17		F	266	12	0.968	0.005		=C17/E17	=SQRT((D17/E17)^2+(C17*F17/(E17^2))^2)		='Survey data'!AK213	='Survey data'!AK214	='Survey data'!AK215	='Survey data'!AK216	0.478	
18	Beef	M	37	3	0.258	0.024		=C18/E18	=SQRT((D18/E18)^2+(C18*F18/(E18^2))^2)		='Survey data'!BO87	='Survey data'!BO88	='Survey data'!BO89	='Survey data'!BO90	0.522	=(H1
19		F	17	2	0.194	0.014		=C19/E19	=SQRT((D19/E19)^2+(C19*F19/(E19^2))^2)		='Survey data'!BO213	='Survey data'!BO214	='Survey data'!BO215	='Survey data'!BO216	0.478	
20	Pork	M	12	2	0.169	0.012		=C20/E20	=SQRT((D20/E20)^2+(C20*F20/(E20^2))^2)		='Survey data'!BY87	='Survey data'!BY88	='Survey data'!BY89	='Survey data'!BY90	0.522	=(H2
21		F	6	1	0.132	0.014		=C21/E21	=SQRT((D21/E21)^2+(C21*F21/(E21^2))^2)		='Survey data'!BY213	='Survey data'!BY214	='Survey data'!BY215	='Survey data'!BY216	0.478	
22	Wild Game	M	2	1	0.012	0.007		=C22/E22	=SQRT((D22/E22)^2+(C22*F22/(E22^2))^2)		='Survey data'!CI87	='Survey data'!CI88	='Survey data'!CI89	='Survey data'!CI90	0.522	=(H2
23		F	1	1	0.01	0.004		=C23/E23	=SQRT((D23/E23)^2+(C23*F23/(E23^2))^2)		='Survey data'!CI213	='Survey data'!CI214	='Survey data'!CI215	='Survey data'!CI216	0.478	
24	Poultry	M	29	3	0.215	0.012		=C24/E24	=SQRT((D24/E24)^2+(C24*F24/(E24^2))^2)		='Survey data'!BE87	='Survey data'!BE88	='Survey data'!BE89	='Survey data'!BE90	0.522	=(H2
25		F	17	2	0.207	0.018		=C25/E25	=SQRT((D25/E25)^2+(C25*F25/(E25^2))^2)		='Survey data'!BE213	='Survey data'!BE214	='Survey data'!BE215	='Survey data'!BE216	0.478	
26	Milk	M	193	9	0.496	0.02		=C26/E26	=SQRT((D26/E26)^2+(C26*F26/(E26^2))^2)		='Survey data'!DC87	='Survey data'!DC88	='Survey data'!DC89	='Survey data'!DC90	0.522	=(H2
27		F	155	10	0.513	0.025		=C27/E27	=SQRT((D27/E27)^2+(C27*F27/(E27^2))^2)		='Survey data'!DC213	='Survey data'!DC214	='Survey data'!DC215	='Survey data'!DC216	0.478	
28	Eggs	M	29	3	0.239	0.019		=C28/E28	=SQRT((D28/E28)^2+(C28*F28/(E28^2))^2)		='Survey data'!DM87	='Survey data'!DM88	='Survey data'!DM89	='Survey data'!DM90	0.522	=(H2
29		F	18	2	0.189	0.012		=C29/E29	=SQRT((D29/E29)^2+(C29*F29/(E29^2))^2)		='Survey data'!DM213	='Survey data'!DM214	='Survey data'!DM215	='Survey data'!DM216	0.478	
30	Fish	M	12	2	0.093	0.009		=C30/E30	=SQRT((D30/E30)^2+(C30*F30/(E30^2))^2)		='Survey data'!CS87	='Survey data'!CS88	='Survey data'!CS89	='Survey data'!CS90	0.522	=(H3
31		F	9	2	0.078	0.012		=C31/E31	=SQRT((D31/E31)^2+(C31*F31/(E31^2))^2)		='Survey data'!CS213	='Survey data'!CS214	='Survey data'!CS215	='Survey data'!CS216	0.478	
32																

Figure I-2. Image of the Formulas for Columns A through O for the *Consumption rates* Worksheet of the *Consumption rates with uncertainties* Workbook.



Microsoft Excel - Consumption rates with uncertainties

	M	N	O	Q	R	S	U	V	W
1									
2									
3									
4									
5				Consumption Rate, U			Consumption F		
6				Survey Food Groups			Biosphere Model F		
7	Count	SEM	% popul.	Mean		SEM	Mean	SEM	zeta
8	='Survey data'!Q89	='Survey data'!Q90	0.522	=(H8*K8*O8+H9*K9*O9)/1000	=(H8*N8)^2+(K8*I8)^2	=SQRT(R8*(O8^2)+R9*(O9^2))/1000	=Q8	=S8	=LN
9	='Survey data'!Q215	='Survey data'!Q216	0.478		=(H9*N9)^2+(K9*I9)^2				
10	='Survey data'!AA89	='Survey data'!AA90	0.522	=(H10*K10*O10+H11*K11*O11)/1000	=(H10*N10)^2+(K10*I10)^2	=SQRT(R10*(O10^2)+R11*(O11^2))/1000	=Q10	=S10	=LN
11	='Survey data'!AA215	='Survey data'!AA216	0.478		=(H11*N11)^2+(K11*I11)^2				
12	='Survey data'!AU89	='Survey data'!AU90	0.522	=(H12*K12*O12+H13*K13*O13)/1000	=(H12*N12)^2+(K12*I12)^2	=SQRT(R12*(O12^2)+R13*(O13^2))/1000	=Q12+Q14	=SQRT(S12^2+S14^2)	=LN
13	='Survey data'!AU215	='Survey data'!AU216	0.478		=(H13*N13)^2+(K13*I13)^2				
14	='Survey data'!DY89	='Survey data'!DY90	0.522	=(H14*K14*O14+H15*K15*O15)/1000	=(H14*N14)^2+(K14*I14)^2	=SQRT(R14*(O14^2)+R15*(O15^2))/1000			
15	='Survey data'!DY215	='Survey data'!DY216	0.478		=(H15*N15)^2+(K15*I15)^2				
16	='Survey data'!AK89	='Survey data'!AK90	0.522	=(H16*K16*O16+H17*K17*O17)/1000	=(H16*N16)^2+(K16*I16)^2	=SQRT(R16*(O16^2)+R17*(O17^2))/1000	=Q16	=S16	=LN
17	='Survey data'!AK215	='Survey data'!AK216	0.478		=(H17*N17)^2+(K17*I17)^2				
18	='Survey data'!BO89	='Survey data'!BO90	0.522	=(H18*K18*O18+H19*K19*O19)/1000	=(H18*N18)^2+(K18*I18)^2	=SQRT(R18*(O18^2)+R19*(O19^2))/1000	=Q18+Q20+Q22	=SQRT(S18^2+S20^2+S22^2)	=LN
19	='Survey data'!BO215	='Survey data'!BO216	0.478		=(H19*N19)^2+(K19*I19)^2				
20	='Survey data'!BY89	='Survey data'!BY90	0.522	=(H20*K20*O20+H21*K21*O21)/1000	=(H20*N20)^2+(K20*I20)^2	=SQRT(R20*(O20^2)+R21*(O21^2))/1000			
21	='Survey data'!BY215	='Survey data'!BY216	0.478		=(H21*N21)^2+(K21*I21)^2				
22	='Survey data'!CI89	='Survey data'!CI90	0.522	=(H22*K22*O22+H23*K23*O23)/1000	=(H22*N22)^2+(K22*I22)^2	=SQRT(R22*(O22^2)+R23*(O23^2))/1000			
23	='Survey data'!CI215	='Survey data'!CI216	0.478		=(H23*N23)^2+(K23*I23)^2				
24	='Survey data'!BE89	='Survey data'!BE90	0.522	=(H24*K24*O24+H25*K25*O25)/1000	=(H24*N24)^2+(K24*I24)^2	=SQRT(R24*(O24^2)+R25*(O25^2))/1000	=Q24	=S24	=LN
25	='Survey data'!BE215	='Survey data'!BE216	0.478		=(H25*N25)^2+(K25*I25)^2				
26	='Survey data'!DC89	='Survey data'!DC90	0.522	=(H26*K26*O26+H27*K27*O27)/1000	=(H26*N26)^2+(K26*I26)^2	=SQRT(R26*(O26^2)+R27*(O27^2))/1000	=Q26	=S26	=LN
27	='Survey data'!DC215	='Survey data'!DC216	0.478		=(H27*N27)^2+(K27*I27)^2				
28	='Survey data'!DM89	='Survey data'!DM90	0.522	=(H28*K28*O28+H29*K29*O29)/1000	=(H28*N28)^2+(K28*I28)^2	=SQRT(R28*(O28^2)+R29*(O29^2))/1000	=Q28	=S28	=LN
29	='Survey data'!DM215	='Survey data'!DM216	0.478		=(H29*N29)^2+(K29*I29)^2				
30	='Survey data'!CS89	='Survey data'!CS90	0.522	=(H30*K30*O30+H31*K31*O31)/1000	=(H30*N30)^2+(K30*I30)^2	=SQRT(R30*(O30^2)+R31*(O31^2))/1000	=Q30	=S30	=LN
31	='Survey data'!CS215	='Survey data'!CS216	0.478		=(H31*N31)^2+(K31*I31)^2				
32									

Figure I-3. Image of the Formulas for Columns M through V for the *Consumption rates* Worksheet of the *Consumption rates with uncertainties* Workbook.

ATTACHMENT II

CALCULATION OF INHALATION DOSE CONVERSION FACTOR RATIOS FOR DIFFERENT SIZE PARTICLES

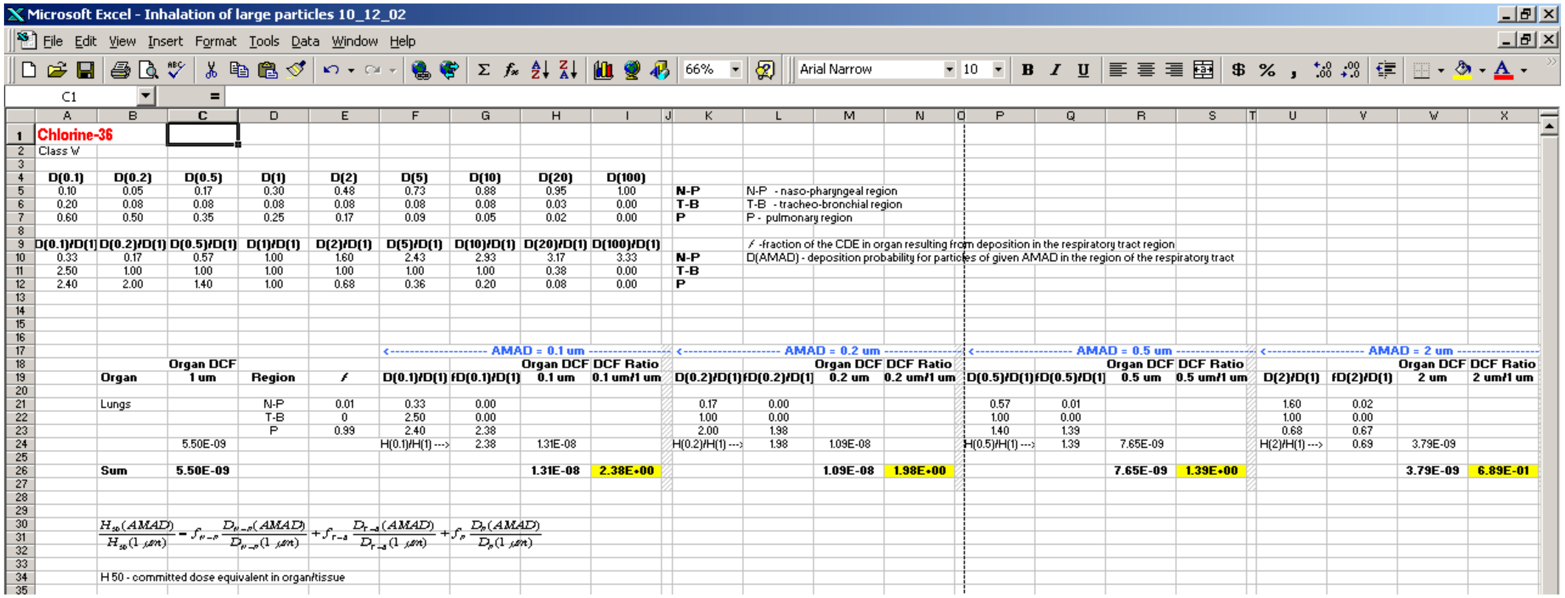
CALCULATION OF INHALATION DOSE CONVERSION FACTOR RATIOS FOR DIFFERENT SIZE PARTICLES

This attachment explains the spreadsheet calculations of inhalation DCF ratios for particles with the activity median aerodynamic diameter (AMAD) in the range from 0.1 to 100 μm. The calculations were done using standard function of Microsoft Excel 97 SR-2. The calculation method is described in Section 6.5.5.2. The calculations were done in the Excel workbook named **Inhalation of large particles.xls**. The file is in Attachment III. The workbook consists of twenty-nine worksheets. First twenty-seven worksheets contain calculations of the inhalation DCF ratio for individual primary radionuclides of interest (except C-14, which is considered to be present in the atmosphere in gaseous form). The names of the worksheets are the same as the radionuclide symbols, e.g., the worksheet named **Cl-36** contains calculations of inhalation DCF ratios for ^{36}Cl. These worksheets are shown in Figures II-1 through II-27 (some figures are presented in two parts, a and b). The twenty-eighth worksheet, named **Summary**, contains the summary of the DCF ratios (presented in the main body of the report in Table 6.5-6) and their graphical representation (Figure 6.5-1 in the report). This worksheet in shown in Figure II-29.

The last worksheet, named **Np-237(2)** contains an example of formulas used to calculate inhalation DCF ratios. This worksheet is shown in Figure II-28. The DCF ratios are calculated as follows:

First, the deposition probabilities for particles of 0.1, 0.2, 0.5, 1.0, 2, 5, 10 20, and 100 μm in the three regions (naso-pharyngeal, tracheo-bronchial, and pulmonary, of respiratory tract are read from Figure 5.1 in ICRP Publication 30 (ICRP 1979 [110386]). These probabilities, denoted as D(0.1), D(0.2), and so on, are listed in rows 5 through 7, and columns A through I. In rows 10 through 12, columns A through I, the ratios of deposition probabilities for particles with a given AMAD and particles with AMAD = 1 μm are calculated.

In the next step, for every organ listed for a given radionuclide, fractions of dose originating in the naso-pharyngeal, tracheo-bronchial, and pulmonary regions are read from the tables given in ICRP-30 (ICRP 1978 [101076], pp. 84-85, 192-193, 231-232, 236-237, 289-290, 318, 322-323, 333-334, 356-357, 362, 364-365, 371, 378, 410-411, 414-415, 418-419, 424-425, 456, 466-467; ICRP 1981 [153056], pp. 19, 195, 660-661, 739; ICRP 1982 [153057], pp. 790, 827; ICRP 1982 [163147], pp. 158-159). These values are listed in column E under the header with a letter *f*. For every organ, these values are multiplied by the appropriate deposition probability ratios in the three regions of respiratory tract and added up (e.g., column G for 0.1 μm AMAD; column L for 0.2 μm AMAD). The organ DCF for a given AMAD is calculated as the product of the DCF in that organ for 1 μm (column C) and the sum calculated in the previous step (e.g., column H for 0.1 μm AMAD; column M for 0.2 μm AMAD). The organ DCFs are added to get the CEDE for a given AMAD and divided by the CEDE for 1 μm AMAD (e.g., column I for 0.1 μm AMAD; column N for 0.2 μm AMAD).



Chlorine-36

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	N-P
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	T-B
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	P

D(0.1)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	N-P
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	T-B
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	P

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

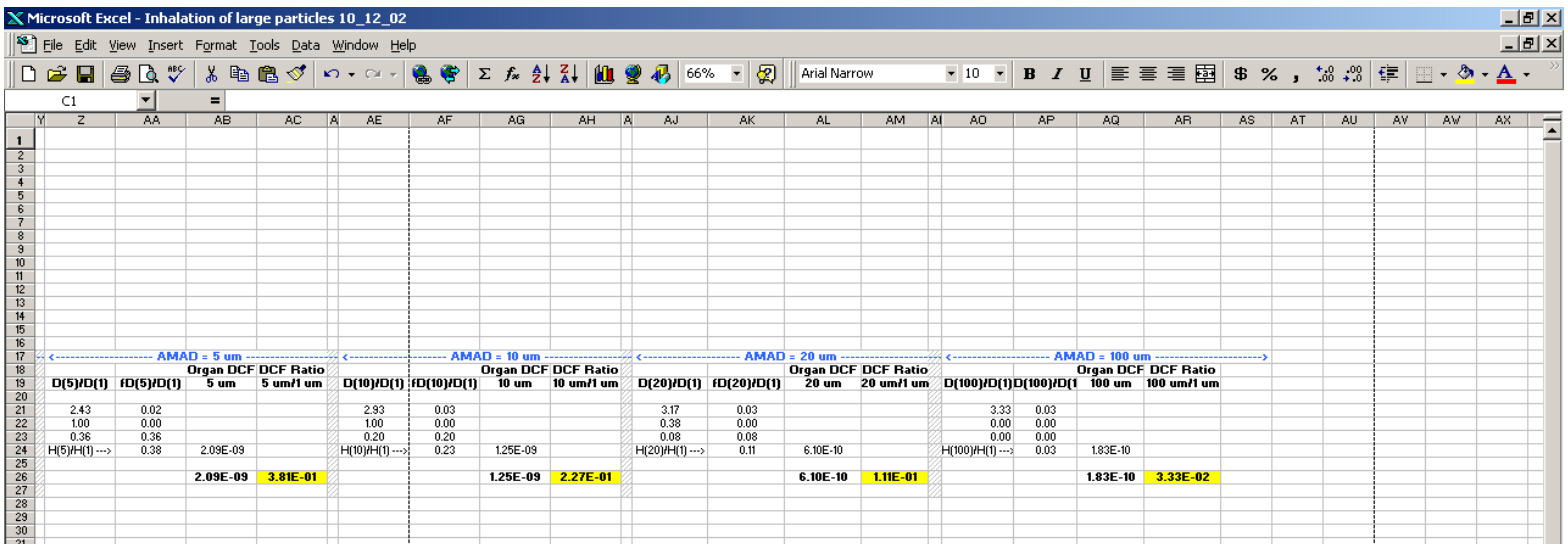
f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*	AMAD = 0.1 um: D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um	AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Lungs		N-P	0.01	0.33	0.00			0.17	0.00		
		T-B	0	2.50	0.00			1.00	0.00		
		P	0.99	2.40	2.38			2.00	1.98		
	5.50E-09			H(0.1)/H(1) --->	2.38	1.31E-08		H(0.2)/H(1) --->	1.98	1.09E-08	
Sum	5.50E-09					1.31E-08	2.38E+00			1.09E-08	1.98E+00

AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.57	0.01			1.60	0.02		
1.00	0.00			1.00	0.00		
1.40	1.39			0.68	0.67		
H(0.5)/H(1) --->	1.39	7.65E-09		H(2)/H(1) --->	0.69	3.79E-09	
		7.65E-09	1.39E+00			3.79E-09	6.89E-01

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.43	0.02			2.93	0.03		
1.00	0.00			1.00	0.00		
0.36	0.36			0.20	0.20		
H(5)/H(1) --->	0.38	2.09E-09		H(10)/H(1) --->	0.23	1.25E-09	
		2.09E-09	3.81E-01			1.25E-09	2.27E-01

AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	D(100)/D(1	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.17	0.03			3.33	0.03		
0.38	0.00			0.00	0.00		
0.08	0.08			0.00	0.00		
H(20)/H(1) --->	0.11	6.10E-10		H(100)/H(1) --->	0.03	1.83E-10	
		6.10E-10	1.11E-01			1.83E-10	3.33E-02

Figure II-1. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Chlorine-36

Microsoft Excel - Inhalation of large particles 10_12_02

Selenium-79

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

D(0.1)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

N-P - naso-pharyngeal region

T-B - tracheo-bronchial region

P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region

D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

AMAD = 0.1 um

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Gonads		N-P	0.46	0.33	0.15		
		T-B	0.14	2.50	0.35		
		P	0.4	2.40	0.96		
	1.50E-10			H(0.1)/H(1) --->	1.46	2.20E-10	
Lungs		N-P	0.03	0.33	0.01		
		T-B	0.01	2.50	0.03		
		P	0.96	2.40	2.30		
	1.20E-09			H(0.1)/H(1) --->	2.34	2.81E-09	
Kidneys		N-P	0.46	0.33	0.15		
		T-B	0.14	2.50	0.35		
		P	0.4	2.40	0.96		
	5.00E-10			H(0.1)/H(1) --->	1.46	7.32E-10	
Liver		N-P	0.46	0.33	0.15		
		T-B	0.14	2.50	0.35		
		P	0.4	2.40	0.96		
	2.60E-10			H(0.1)/H(1) --->	1.46	3.80E-10	
Pancreas		N-P	0.46	0.33	0.15		
		T-B	0.14	2.50	0.35		
		P	0.4	2.40	0.96		
	1.50E-10			H(0.1)/H(1) --->	1.46	2.20E-10	
Spleen		N-P	0.46	0.33	0.15		
		T-B	0.14	2.50	0.35		
		P	0.4	2.40	0.96		
	1.70E-10			H(0.1)/H(1) --->	1.46	2.49E-10	
Sum	**2.43E-09**					**4.61E-09**	**1.90E+00**

AMAD = 0.2 um

Organ	Region	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads	N-P	0.17	0.08		
	T-B	1.00	0.14		
	P	2.00	0.80		
		H(0.2)/H(1) --->	1.02	1.53E-10	
Lungs	N-P	0.17	0.01		
	T-B	1.00	0.01		
	P	2.00	1.92		
		H(0.2)/H(1) --->	1.94	2.32E-09	
Kidneys	N-P	0.17	0.08		
	T-B	1.00	0.14		
	P	2.00	0.80		
		H(0.2)/H(1) --->	1.02	5.08E-10	
Liver	N-P	0.17	0.08		
	T-B	1.00	0.14		
	P	2.00	0.80		
		H(0.2)/H(1) --->	1.02	2.64E-10	
Pancreas	N-P	0.17	0.08		
	T-B	1.00	0.14		
	P	2.00	0.80		
		H(0.2)/H(1) --->	1.02	1.53E-10	
Spleen	N-P	0.17	0.08		
	T-B	1.00	0.14		
	P	2.00	0.80		
		H(0.2)/H(1) --->	1.02	1.73E-10	
Sum				**3.57E-09**	**1.47E+00**

AMAD = 0.5 um

Organ	Region	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
Gonads	N-P	0.57	0.26		
	T-B	1.00	0.14		
	P	1.40	0.56		
		H(0.5)/H(1) --->	0.96	1.44E-10	
Lungs	N-P	0.57	0.02		
	T-B	1.00	0.01		
	P	1.40	1.34		
		H(0.5)/H(1) --->	1.37	1.65E-09	
Kidneys	N-P	0.57	0.26		
	T-B	1.00	0.14		
	P	1.40	0.56		
		H(0.5)/H(1) --->	0.96	4.80E-10	
Liver	N-P	0.57	0.26		
	T-B	1.00	0.14		
	P	1.40	0.56		
		H(0.5)/H(1) --->	0.96	2.50E-10	
Pancreas	N-P	0.57	0.26		
	T-B	1.00	0.14		
	P	1.40	0.56		
		H(0.5)/H(1) --->	0.96	1.44E-10	
Spleen	N-P	0.57	0.26		
	T-B	1.00	0.14		
	P	1.40	0.56		
		H(0.5)/H(1) --->	0.96	1.63E-10	
Sum				**2.83E-09**	**1.16E+00**

AMAD = 2 um

Organ	Region	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	N-P	1.60	0.74		
	T-B	1.00	0.14		
	P	0.68	0.27		
		H(2)/H(1) --->	1.15	1.72E-10	
Lungs	N-P	1.60	0.05		
	T-B	1.00	0.01		
	P	0.68	0.65		
		H(2)/H(1) --->	0.71	8.53E-10	
Kidneys	N-P	1.60	0.74		
	T-B	1.00	0.14		
	P	0.68	0.27		
		H(2)/H(1) --->	1.15	5.74E-10	
Liver	N-P	1.60	0.74		
	T-B	1.00	0.14		
	P	0.68	0.27		
		H(2)/H(1) --->	1.15	2.98E-10	
Pancreas	N-P	1.60	0.74		
	T-B	1.00	0.14		
	P	0.68	0.27		
		H(2)/H(1) --->	1.15	1.72E-10	
Spleen	N-P	1.60	0.74		
	T-B	1.00	0.14		
	P	0.68	0.27		
		H(2)/H(1) --->	1.15	1.95E-10	
Sum				**2.27E-09**	**9.32E-01**

$$\frac{H_{50}(AMAD)}{H_{50}(1\,\mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\,\mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\,\mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\,\mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-2a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Selenium-79

Microsoft Excel - Inhalation of large particles 10_12_02

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Z74 =

Selenium-79

Row	Z	AA	AB	AC	AE	AF	AG	AH
17	<-------------- AMAD = 5 um			-------------->	<-------------- AMAD = 10 um			-------------->
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um
21	2.43	1.12			2.93	1.35		
22	1.00	0.14			1.00	0.14		
23	0.36	0.14			0.20	0.08		
24	H(5)/H(1) --->	1.40	2.11E-10		H(10)/H(1) --->	1.57	2.35E-10	
26	2.43	0.07			2.93	0.09		
27	1.00	0.01			1.00	0.01		
28	0.36	0.35			0.20	0.19		
29	H(5)/H(1) --->	0.43	5.14E-10		H(10)/H(1) --->	0.29	3.48E-10	
31	2.43	1.12			2.93	1.35		
32	1.00	0.14			1.00	0.14		
33	0.36	0.14			0.20	0.08		
34	H(5)/H(1) --->	1.40	7.02E-10		H(10)/H(1) --->	1.57	7.85E-10	
36	2.43	1.12			2.93	1.35		
37	1.00	0.14			1.00	0.14		
38	0.36	0.14			0.20	0.08		
39	H(5)/H(1) --->	1.40	3.65E-10		H(10)/H(1) --->	1.57	4.08E-10	
41	2.43	1.12			2.93	1.35		
42	1.00	0.14			1.00	0.14		
43	0.36	0.14			0.20	0.08		
44	H(5)/H(1) --->	1.40	2.11E-10		H(10)/H(1) --->	1.57	2.35E-10	
46	2.43	1.12			2.93	1.35		
47	1.00	0.14			1.00	0.14		
48	0.36	0.14			0.20	0.08		
49	H(5)/H(1) --->	1.40	2.39E-10		H(10)/H(1) --->	1.57	2.67E-10	
51			**2.24E-09**	**9.22E-01**			**2.28E-09**	**9.38E-01**

Row	AJ	AK	AL	AM	AO	AP	AQ	AR
17	<-------------- AMAD = 20 um			-------------->	<-------------- AMAD = 100 um			-------------->
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	3.17	1.46			3.33	1.53		
22	0.38	0.05			0.00	0.00		
23	0.08	0.03			0.00	0.00		
24	H(20)/H(1) --->	1.54	2.31E-10		H(100)/H(1) --->	1.53	2.30E-10	
26	3.17	0.10			3.33	0.10		
27	0.38	0.00			0.00	0.00		
28	0.08	0.08			0.00	0.00		
29	H(20)/H(1) --->	0.18	2.11E-10		H(100)/H(1) --->	0.10	1.20E-10	
31	3.17	1.46			3.33	1.53		
32	0.38	0.05			0.00	0.00		
33	0.08	0.03			0.00	0.00		
34	H(20)/H(1) --->	1.54	7.71E-10		H(100)/H(1) --->	1.53	7.67E-10	
36	3.17	1.46			3.33	1.53		
37	0.38	0.05			0.00	0.00		
38	0.08	0.03			0.00	0.00		
39	H(20)/H(1) --->	1.54	4.01E-10		H(100)/H(1) --->	1.53	3.99E-10	
41	3.17	1.46			3.33	1.53		
42	0.38	0.05			0.00	0.00		
43	0.08	0.03			0.00	0.00		
44	H(20)/H(1) --->	1.54	2.31E-10		H(100)/H(1) --->	1.53	2.30E-10	
46	3.17	1.46			3.33	1.53		
47	0.38	0.05			0.00	0.00		
48	0.08	0.03			0.00	0.00		
49	H(20)/H(1) --->	1.54	2.62E-10		H(100)/H(1) --->	1.53	2.61E-10	
51			**2.11E-09**	**8.67E-01**			**2.01E-09**	**8.26E-01**

Figure II-2b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Selenium-79

Microsoft Excel - Inhalation of large particles 10_12_02

Strontium-90

Class D

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

	D(0.1)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

AMAD = 0.1 um

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
R Marrow		N-P	0.37	0.33	0.12		
		T-B	0.15	2.50	0.38		
		P	0.48	2.40	1.15		
	4.00E-08			H(0.1)/H(1) --->	1.65	6.60E-08	
Bone Surf		N-P	0.37	0.33	0.12		
		T-B	0.15	2.50	0.38		
		P	0.48	2.40	1.15		
	2.20E-08			H(0.1)/H(1) --->	1.65	3.63E-08	
Sum	6.20E-08					1.02E-07	1.65E+00

Organ	Region	AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
R Marrow	N-P	0.17	0.06			0.57	0.21			1.60	0.59		
	T-B	1.00	0.15			1.00	0.15			1.00	0.15		
	P	2.00	0.96			1.40	0.67			0.68	0.33		
		H(0.2)/H(1) --->	1.17	4.69E-08		H(0.5)/H(1) --->	1.03	4.13E-08		H(2)/H(1) --->	1.07	4.27E-08	
Bone Surf	N-P	0.17	0.06			0.57	0.21			1.60	0.59		
	T-B	1.00	0.15			1.00	0.15			1.00	0.15		
	P	2.00	0.96			1.40	0.67			0.68	0.33		
		H(0.2)/H(1) --->	1.17	2.58E-08		H(0.5)/H(1) --->	1.03	2.27E-08		H(2)/H(1) --->	1.07	2.35E-08	
Sum				7.26E-08	1.17E+00			6.40E-08	1.03E+00			6.62E-08	1.07E+00

Microsoft Excel - Inhalation of large particles 10_12_02

Strontium-90

AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
2.43	0.90			2.93	1.09			3.17	1.17			3.33	1.23		
1.00	0.15			1.00	0.15			0.38	0.06			0.00	0.00		
0.36	0.17			0.20	0.10			0.08	0.04			0.00	0.00		
H(5)/H(1) --->	1.22	4.89E-08		H(10)/H(1) --->	1.33	5.33E-08		H(20)/H(1) --->	1.27	5.07E-08		H(100)/H(1) --->	1.23	4.93E-08	
2.43	0.90			2.93	1.09			3.17	1.17			3.33	1.23		
1.00	0.15			1.00	0.15			0.38	0.06			0.00	0.00		
0.36	0.17			0.20	0.10			0.08	0.04			0.00	0.00		
H(5)/H(1) --->	1.22	2.69E-08		H(10)/H(1) --->	1.33	2.93E-08		H(20)/H(1) --->	1.27	2.79E-08		H(100)/H(1) --->	1.23	2.71E-08	
		7.58E-08	1.22E+00			8.25E-08	1.33E+00			7.85E-08	1.27E+00			7.65E-08	1.23E+00

Figure II-3. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Strontium-90

Microsoft Excel - Inhalation of large particles 10_12_02

Technetium-99

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

	D(0.1)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	f
Lungs		N-P	0
		T-B	0
		P	1
	2.00E-09		
Sum	2.00E-09		

AMAD = 0.1 um

D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
0.33	0.00		
2.50	0.00		
2.40	2.40		
H(0.1)/H(1) --->	2.40	4.80E-09	
		4.80E-09	2.40E+00

AMAD = 0.2 um

D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
0.17	0.00		
1.00	0.00		
2.00	2.00		
H(0.2)/H(1) --->	2.00	4.00E-09	
		4.00E-09	2.00E+00

AMAD = 0.5 um

D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
0.57	0.00		
1.00	0.00		
1.40	1.40		
H(0.5)/H(1) --->	1.40	2.80E-09	
		2.80E-09	1.40E+00

AMAD = 2 um

D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
1.60	0.00		
1.00	0.00		
0.68	0.68		
H(2)/H(1) --->	0.68	1.36E-09	
		1.36E-09	6.80E-01

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Microsoft Excel - Inhalation of large particles 10_12_02

Technetium-99

AMAD = 5 um

D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
2.43	0.00		
1.00	0.00		
0.36	0.36		
H(5)/H(1) --->	0.36	7.20E-10	
		7.20E-10	3.60E-01

AMAD = 10 um

D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.93	0.00		
1.00	0.00		
0.20	0.20		
H(10)/H(1) --->	0.20	4.00E-10	
		4.00E-10	2.00E-01

AMAD = 20 um

D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
3.17	0.00		
0.38	0.00		
0.08	0.08		
H(20)/H(1) --->	0.08	1.60E-10	
		1.60E-10	8.00E-02

AMAD = 100 um

D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.33	0.00		
0.00	0.00		
0.00	0.00		
H(100)/H(1) --->	0.00	0.00E+00	
		0.00E+00	0.00E+00

Figure II-4. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Technetium-99

Microsoft Excel - Inhalation of large particles 10_12_02

Tin-126

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

	D(0.1)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	f
R Marrow		N-P	0.25
		T-B	0.28
		P	0.47
	2.00E-09		
Lungs		N-P	0.01
		T-B	0.01
		P	0.98
	1.80E-08		
Sum	2.00E-08		

AMAD = 0.1 um

D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
0.33	0.08		
2.50	0.70		
2.40	1.13		
H(0.1)/H(1) --->	1.91	3.82E-09	
0.33	0.00		
2.50	0.03		
2.40	2.35		
H(0.1)/H(1) --->	2.38	4.28E-08	
		4.67E-08	2.33E+00

AMAD = 0.2 um

D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
0.17	0.04		
1.00	0.28		
2.00	0.94		
H(0.2)/H(1) --->	1.26	2.52E-09	
0.17	0.00		
1.00	0.01		
2.00	1.96		
H(0.2)/H(1) --->	1.97	3.55E-08	
		3.80E-08	1.90E+00

AMAD = 0.5 um

D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
0.57	0.14		
1.00	0.28		
1.40	0.66		
H(0.5)/H(1) --->	1.08	2.16E-09	
0.57	0.01		
1.00	0.01		
1.40	1.37		
H(0.5)/H(1) --->	1.39	2.50E-08	
		2.71E-08	1.36E+00

AMAD = 2 um

D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
1.60	0.40		
1.00	0.28		
0.68	0.32		
H(2)/H(1) --->	1.00	2.00E-09	
1.60	0.02		
1.00	0.01		
0.68	0.67		
H(2)/H(1) --->	0.69	1.25E-08	
		1.45E-08	7.23E-01

Microsoft Excel - Inhalation of large particles 10_12_02

Tin-126

AMAD = 5 um

D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
2.43	0.61		
1.00	0.28		
0.36	0.17		
H(5)/H(1) --->	1.06	2.12E-09	
2.43	0.02		
1.00	0.01		
0.36	0.35		
H(5)/H(1) --->	0.39	6.97E-09	
		9.08E-09	4.54E-01

AMAD = 10 um

D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.93	0.73		
1.00	0.28		
0.20	0.09		
H(10)/H(1) --->	1.11	2.21E-09	
2.93	0.03		
1.00	0.01		
0.20	0.20		
H(10)/H(1) --->	0.24	4.24E-09	
		6.45E-09	3.23E-01

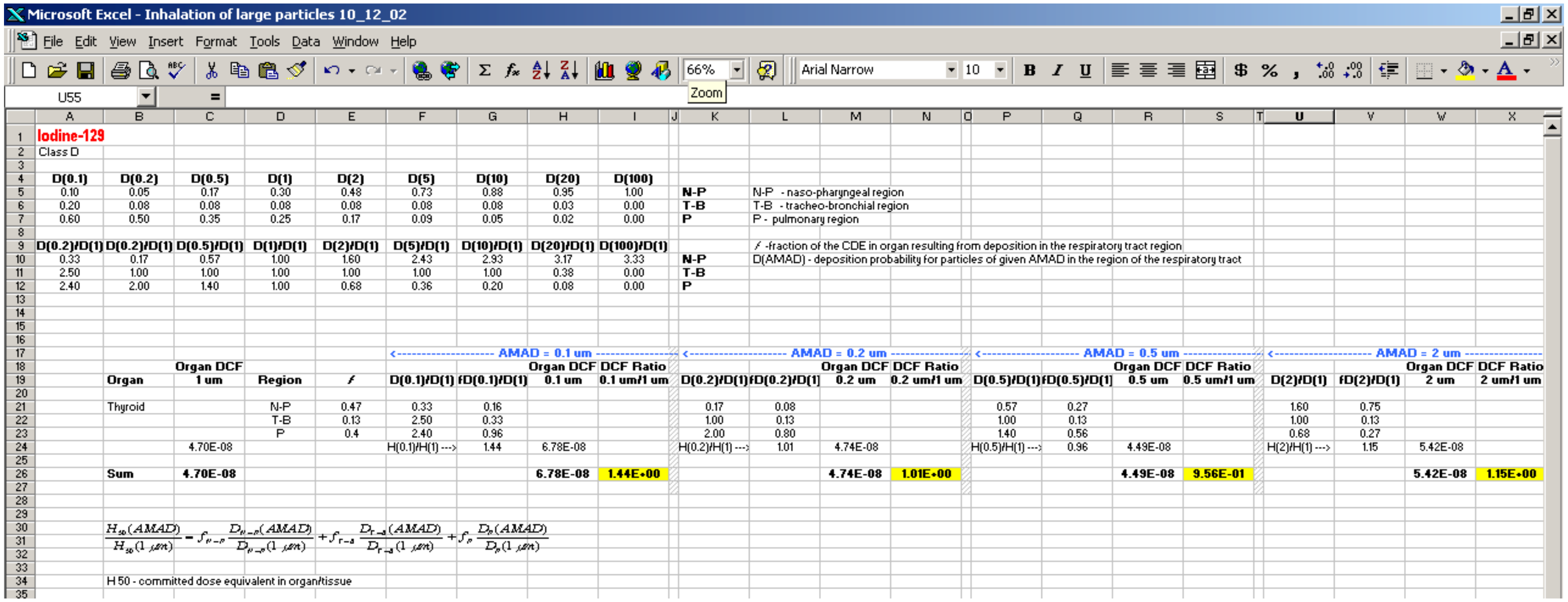
AMAD = 20 um

D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
3.17	0.79		
0.38	0.11		
0.08	0.04		
H(20)/H(1) --->	0.93	1.87E-09	
3.17	0.03		
0.38	0.00		
0.08	0.08		
H(20)/H(1) --->	0.11	2.05E-09	
		3.92E-09	1.96E-01

AMAD = 100 um

D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.33	0.83		
0.00	0.00		
0.00	0.00		
H(100)/H(1) --->	0.83	1.67E-09	
3.33	0.03		
0.00	0.00		
0.00	0.00		
H(100)/H(1) --->	0.03	6.00E-10	
		2.27E-09	1.13E-01

Figure II-5. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Tin-126



Microsoft Excel - Inhalation of large particles 10_12_02

Iodine-129

Class D

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	N-P
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	T-B
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	P

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	N-P
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	T-B
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	P

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

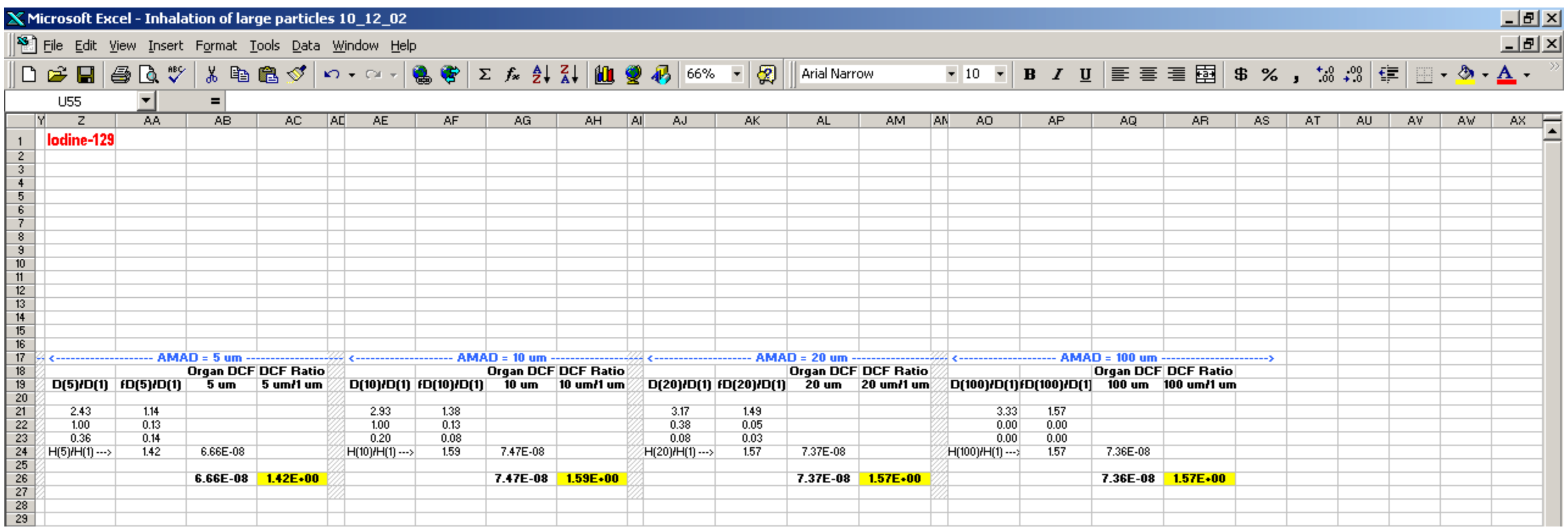
f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*	AMAD = 0.1 um: D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Thyroid		N-P	0.47	0.33	0.16		
		T-B	0.13	2.50	0.33		
		P	0.4	2.40	0.96		
	4.70E-08			H(0.1)/H(1) --->	1.44	6.78E-08	
Sum	**4.70E-08**					**6.78E-08**	**1.44E+00**

AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.17	0.08			0.57	0.27			1.60	0.75		
1.00	0.13			1.00	0.13			1.00	0.13		
2.00	0.80			1.40	0.56			0.68	0.27		
H(0.2)/H(1) --->	1.01	4.74E-08		H(0.5)/H(1) --->	0.96	4.49E-08		H(2)/H(1) --->	1.15	5.42E-08	
		4.74E-08	**1.01E+00**			**4.49E-08**	**9.56E-01**			**5.42E-08**	**1.15E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



Microsoft Excel - Inhalation of large particles 10_12_02

Iodine-129

AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.43	1.14			2.93	1.38		
1.00	0.13			1.00	0.13		
0.36	0.14			0.20	0.08		
H(5)/H(1) --->	1.42	6.66E-08		H(10)/H(1) --->	1.59	7.47E-08	
		6.66E-08	**1.42E+00**			**7.47E-08**	**1.59E+00**

AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.17	1.49			3.33	1.57		
0.38	0.05			0.00	0.00		
0.08	0.03			0.00	0.00		
H(20)/H(1) --->	1.57	7.37E-08		H(100)/H(1) --->	1.57	7.36E-08	
		7.37E-08	**1.57E+00**			**7.36E-08**	**1.57E+00**

Figure II-6. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Iodine-129

Microsoft Excel - Inhalation of large particles 10_12_02

Cesium-135

Class D

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
D(0.2)/D(1)	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

				AMAD = 0.1 um				AMAD = 0.2 um				AMAD = 0.5 um				AMAD = 2 um			
Organ	**Organ DCF 1 um**	**Region**	**f**	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**Organ DCF 0.1 um**	**DCF Ratio 0.1 um/1 um**	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**Organ DCF 0.2 um**	**DCF Ratio 0.2 um/1 um**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**Organ DCF 0.5 um**	**DCF Ratio 0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**Organ DCF 2 um**	**DCF Ratio 2 um/1 um**
Gonads		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	3.00E-10			H(0.1)/H(1) --->	1.44	4.33E-10		H(0.2)/H(1) --->	1.01	3.03E-10		H(0.5)/H(1) --->	0.96	2.87E-10		H(2)/H(1) --->	1.15	3.46E-10	
Breast		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	1.80E-10			H(0.1)/H(1) --->	1.44	2.60E-10		H(0.2)/H(1) --->	1.01	1.82E-10		H(0.5)/H(1) --->	0.96	1.72E-10		H(2)/H(1) --->	1.15	2.08E-10	
R Marrow		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	1.40E-10			H(0.1)/H(1) --->	1.44	2.02E-10		H(0.2)/H(1) --->	1.01	1.41E-10		H(0.5)/H(1) --->	0.96	1.34E-10		H(2)/H(1) --->	1.15	1.62E-10	
Lungs		N-P	0.41	0.33	0.14			0.17	0.07			0.57	0.23			1.60	0.66		
		T-B	0.11	2.50	0.28			1.00	0.11			1.00	0.11			1.00	0.11		
		P	0.48	2.40	1.15			2.00	0.96			1.40	0.67			0.68	0.33		
	1.70E-10			H(0.1)/H(1) --->	1.56	2.66E-10		H(0.2)/H(1) --->	1.14	1.94E-10		H(0.5)/H(1) --->	1.01	1.72E-10		H(2)/H(1) --->	1.09	1.86E-10	
Thyroid		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	3.60E-11			H(0.1)/H(1) --->	1.44	5.19E-11		H(0.2)/H(1) --->	1.01	3.63E-11		H(0.5)/H(1) --->	0.96	3.44E-11		H(2)/H(1) --->	1.15	4.15E-11	
Bone Surf		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	3.60E-11			H(0.1)/H(1) --->	1.44	5.19E-11		H(0.2)/H(1) --->	1.01	3.63E-11		H(0.5)/H(1) --->	0.96	3.44E-11		H(2)/H(1) --->	1.15	4.15E-11	
ST Wall		N-P	0.48	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.77		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.39	2.40	0.94			2.00	0.78			1.40	0.55			0.68	0.27		
	7.30E-11			H(0.1)/H(1) --->	1.42	1.04E-10		H(0.2)/H(1) --->	0.99	7.23E-11		H(0.5)/H(1) --->	0.95	6.92E-11		H(2)/H(1) --->	1.16	8.49E-11	
SI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	7.20E-11			H(0.1)/H(1) --->	1.44	1.04E-10		H(0.2)/H(1) --->	1.01	7.26E-11		H(0.5)/H(1) --->	0.96	6.89E-11		H(2)/H(1) --->	1.15	8.31E-11	
ULI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	7.20E-11			H(0.1)/H(1) --->	1.44	1.04E-10		H(0.2)/H(1) --->	1.01	7.26E-11		H(0.5)/H(1) --->	0.96	6.89E-11		H(2)/H(1) --->	1.15	8.31E-11	
LLI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	7.20E-11			H(0.1)/H(1) --->	1.44	1.04E-10		H(0.2)/H(1) --->	1.01	7.26E-11		H(0.5)/H(1) --->	0.96	6.89E-11		H(2)/H(1) --->	1.15	8.31E-11	
Remainder		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
		T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
		P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
	7.20E-11			H(0.1)/H(1) --->	1.44	1.04E-10		H(0.2)/H(1) --->	1.01	7.26E-11		H(0.5)/H(1) --->	0.96	6.89E-11		H(2)/H(1) --->	1.15	8.31E-11	
Sum	**1.22E-09**					**1.78E-09**	**1.46E+00**			**1.25E-09**	**1.03E+00**			**1.18E-09**	**9.64E-01**			**1.40E-09**	**1.15E+00**

Figure II-7a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Cesium-135

Microsoft Excel - Inhalation of large particles 10_12_02

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U55 =

	Z	AA	AB	AC	AE	AF	AG	AH	AJ	AK	AL	AM	AO	AP	AQ	AR
1	Cesium-135															
17	<------------------- AMAD = 5 um -----------------				<------------------- AMAD = 10 um -----------------				<------------------- AMAD = 20 um -----------------				<------------------- AMAD = 100 um ------------------->			
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
22	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
23	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
24	H(5)/H(1) --->	1.42	4.25E-10		H(10)/H(1) --->	1.59	4.77E-10		H(20)/H(1) --->	1.57	4.71E-10		H(100)/H(1) --->	1.57	4.70E-10	
26	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
27	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
28	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
29	H(5)/H(1) --->	1.42	2.55E-10		H(10)/H(1) --->	1.59	2.86E-10		H(20)/H(1) --->	1.57	2.82E-10		H(100)/H(1) --->	1.57	2.82E-10	
31	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
32	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
33	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
34	H(5)/H(1) --->	1.42	1.98E-10		H(10)/H(1) --->	1.59	2.22E-10		H(20)/H(1) --->	1.57	2.20E-10		H(100)/H(1) --->	1.57	2.19E-10	
36	2.43	1.00			2.93	1.20			3.17	1.30			3.33	1.37		
37	1.00	0.11			1.00	0.11			0.38	0.04			0.00	0.00		
38	0.36	0.17			0.20	0.10			0.08	0.04			0.00	0.00		
39	H(5)/H(1) --->	1.28	2.18E-10		H(10)/H(1) --->	1.41	2.39E-10		H(20)/H(1) --->	1.38	2.34E-10		H(100)/H(1) --->	1.37	2.32E-10	
41	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
42	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
43	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
44	H(5)/H(1) --->	1.42	5.10E-11		H(10)/H(1) --->	1.59	5.72E-11		H(20)/H(1) --->	1.57	5.65E-11		H(100)/H(1) --->	1.57	5.64E-11	
46	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
47	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
48	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
49	H(5)/H(1) --->	1.42	5.10E-11		H(10)/H(1) --->	1.59	5.72E-11		H(20)/H(1) --->	1.57	5.65E-11		H(100)/H(1) --->	1.57	5.64E-11	
51	2.43	1.17			2.93	1.41			3.17	1.52			3.33	1.60		
52	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
53	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
54	H(5)/H(1) --->	1.44	1.05E-10		H(10)/H(1) --->	1.62	1.18E-10		H(20)/H(1) --->	1.60	1.17E-10		H(100)/H(1) --->	1.60	1.17E-10	
56	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
57	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
58	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
59	H(5)/H(1) --->	1.42	1.02E-10		H(10)/H(1) --->	1.59	1.14E-10		H(20)/H(1) --->	1.57	1.13E-10		H(100)/H(1) --->	1.57	1.13E-10	
61	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
62	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
63	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
64	H(5)/H(1) --->	1.42	1.02E-10		H(10)/H(1) --->	1.59	1.14E-10		H(20)/H(1) --->	1.57	1.13E-10		H(100)/H(1) --->	1.57	1.13E-10	
66	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
67	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
68	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
69	H(5)/H(1) --->	1.42	1.02E-10		H(10)/H(1) --->	1.59	1.14E-10		H(20)/H(1) --->	1.57	1.13E-10		H(100)/H(1) --->	1.57	1.13E-10	
71	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
72	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
73	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
74	H(5)/H(1) --->	1.42	1.02E-10		H(10)/H(1) --->	1.59	1.14E-10		H(20)/H(1) --->	1.57	1.13E-10		H(100)/H(1) --->	1.57	1.13E-10	
76			**1.71E-09**	**1.40E+00**			**1.91E-09**	**1.57E+00**			**1.89E-09**	**1.54E+00**			**1.88E-09**	**1.54E+00**

Figure II-7b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Cesium-135

Microsoft Excel - Inhalation of large particles 10_12_02

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U55 =

Row	A	B	C	D	E	F	G	H	I	K	L
1	**Cesium-137**										
2	Class D										
4	**D(0.1)**	**D(0.2)**	**D(0.5)**	**D(1)**	**D(2)**	**D(5)**	**D(10)**	**D(20)**	**D(100)**		
5	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
6	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
7	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
9	**D(0.2)/D(1**	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		ƒ -fraction of the CDE in organ resulting from deposition in the respiratory tract region
10	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
11	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
12	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

Row	B	C	D	E	F	G	H	I	K	L	M	N	P	Q	R	S	U	V	W	X
17					<------------------- AMAD = 0.1 um -----------------				<------------------- AMAD = 0.2 um -----------------				<------------------- AMAD = 0.5 um -----------------				<------------------- AMAD = 2 um -----------------			
18		**Organ DCF**					**Organ DCF**	**DCF Ratio**			**Organ DCF**	**DCF Ratio**			**Organ DCF**	**DCF Ratio**			**Organ DCF**	**DCF Ratio**
19	**Organ**	**1 um**	**Region**	**ƒ**	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**0.1 um**	**0.1 um/1 um**	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**0.2 um**	**0.2 um/1 um**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**0.5 um**	**0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**2 um**	**2 um/1 um**
21	Gonads		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
22			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
23			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
24		2.20E-09			H(0.1)/H(1) --->	1.44	3.17E-09		H(0.2)/H(1) --->	1.01	2.22E-09		H(0.5)/H(1) --->	0.96	2.10E-09		H(2)/H(1) --->	1.15	2.54E-09	
26	Breast		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
27			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
28			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
29		1.20E-09			H(0.1)/H(1) --->	1.44	1.73E-09		H(0.2)/H(1) --->	1.01	1.21E-09		H(0.5)/H(1) --->	0.96	1.15E-09		H(2)/H(1) --->	1.15	1.38E-09	
31	R Marrow		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
32			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
33			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
34		1.00E-09			H(0.1)/H(1) --->	1.44	1.44E-09		H(0.2)/H(1) --->	1.01	1.01E-09		H(0.5)/H(1) --->	0.96	9.56E-10		H(2)/H(1) --->	1.15	1.15E-09	
36	Lungs		N-P	0.43	0.33	0.14			0.17	0.07			0.57	0.24			1.60	0.69		
37			T-B	0.12	2.50	0.30			1.00	0.12			1.00	0.12			1.00	0.12		
38			P	0.45	2.40	1.08			2.00	0.90			1.40	0.63			0.68	0.31		
39		1.10E-09			H(0.1)/H(1) --->	1.52	1.68E-09		H(0.2)/H(1) --->	1.09	1.20E-09		H(0.5)/H(1) --->	0.99	1.09E-09		H(2)/H(1) --->	1.11	1.23E-09	
41	Thyroid		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
42			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
43			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
44		2.40E-10			H(0.1)/H(1) --->	1.44	3.46E-10		H(0.2)/H(1) --->	1.01	2.42E-10		H(0.5)/H(1) --->	0.96	2.30E-10		H(2)/H(1) --->	1.15	2.77E-10	
46	Bone Surf		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
47			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
48			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
49		2.40E-10			H(0.1)/H(1) --->	1.44	3.46E-10		H(0.2)/H(1) --->	1.01	2.42E-10		H(0.5)/H(1) --->	0.96	2.30E-10		H(2)/H(1) --->	1.15	2.77E-10	
51	SI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
52			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
53			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
54		5.40E-10			H(0.1)/H(1) --->	1.44	7.79E-10		H(0.2)/H(1) --->	1.01	5.45E-10		H(0.5)/H(1) --->	0.96	5.16E-10		H(2)/H(1) --->	1.15	6.23E-10	
56	ULI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
57			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
58			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
59		5.40E-10			H(0.1)/H(1) --->	1.44	7.79E-10		H(0.2)/H(1) --->	1.01	5.45E-10		H(0.5)/H(1) --->	0.96	5.16E-10		H(2)/H(1) --->	1.15	6.23E-10	
61	LLI Wall		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
62			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
63			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
64		5.40E-10			H(0.1)/H(1) --->	1.44	7.79E-10		H(0.2)/H(1) --->	1.01	5.45E-10		H(0.5)/H(1) --->	0.96	5.16E-10		H(2)/H(1) --->	1.15	6.23E-10	
66	Remainder		N-P	0.47	0.33	0.16			0.17	0.08			0.57	0.27			1.60	0.75		
67			T-B	0.13	2.50	0.33			1.00	0.13			1.00	0.13			1.00	0.13		
68			P	0.4	2.40	0.96			2.00	0.80			1.40	0.56			0.68	0.27		
69		1.10E-09			H(0.1)/H(1) --->	1.44	1.59E-09		H(0.2)/H(1) --->	1.01	1.11E-09		H(0.5)/H(1) --->	0.96	1.05E-09		H(2)/H(1) --->	1.15	1.27E-09	
71	**Sum**	**8.70E-09**					**1.26E-08**	**1.45E+00**			**8.86E-09**	**1.02E+00**			**8.36E-09**	**9.61E-01**			**1.00E-08**	**1.15E+00**

Figure II-8a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Cesium-137

Microsoft Excel - Inhalation of large particles 10_12_02

Cesium-137

Row	Z	AA	AB	AC	AE	AF	AG	AH	AJ	AK	AL	AM	AO	AP	AQ	AR
17	<------ AMAD = 5 um ------				<------ AMAD = 10 um ------				<------ AMAD = 20 um ------				<------ AMAD = 100 um ------>			
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
22	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
23	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
24	H(5)/H(1) --->	1.42	3.12E-09		H(10)/H(1) --->	1.59	3.50E-09		H(20)/H(1) --->	1.57	3.45E-09		H(100)/H(1) --->	1.57	3.45E-09	
26	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
27	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
28	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
29	H(5)/H(1) --->	1.42	1.70E-09		H(10)/H(1) --->	1.59	1.91E-09		H(20)/H(1) --->	1.57	1.88E-09		H(100)/H(1) --->	1.57	1.88E-09	
31	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
32	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
33	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
34	H(5)/H(1) --->	1.42	1.42E-09		H(10)/H(1) --->	1.59	1.59E-09		H(20)/H(1) --->	1.57	1.57E-09		H(100)/H(1) --->	1.57	1.57E-09	
36	2.43	1.05			2.93	1.26			3.17	1.36			3.33	1.43		
37	1.00	0.12			1.00	0.12			0.38	0.05			0.00	0.00		
38	0.36	0.16			0.20	0.09			0.08	0.04			0.00	0.00		
39	H(5)/H(1) --->	1.33	1.46E-09		H(10)/H(1) --->	1.47	1.62E-09		H(20)/H(1) --->	1.44	1.59E-09		H(100)/H(1) --->	1.43	1.58E-09	
41	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
42	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
43	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
44	H(5)/H(1) --->	1.42	3.40E-10		H(10)/H(1) --->	1.59	3.81E-10		H(20)/H(1) --->	1.57	3.77E-10		H(100)/H(1) --->	1.57	3.76E-10	
46	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
47	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
48	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
49	H(5)/H(1) --->	1.42	3.40E-10		H(10)/H(1) --->	1.59	3.81E-10		H(20)/H(1) --->	1.57	3.77E-10		H(100)/H(1) --->	1.57	3.76E-10	
51	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
52	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
53	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
54	H(5)/H(1) --->	1.42	7.66E-10		H(10)/H(1) --->	1.59	8.58E-10		H(20)/H(1) --->	1.57	8.47E-10		H(100)/H(1) --->	1.57	8.46E-10	
56	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
57	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
58	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
59	H(5)/H(1) --->	1.42	7.66E-10		H(10)/H(1) --->	1.59	8.58E-10		H(20)/H(1) --->	1.57	8.47E-10		H(100)/H(1) --->	1.57	8.46E-10	
61	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
62	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
63	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
64	H(5)/H(1) --->	1.42	7.66E-10		H(10)/H(1) --->	1.59	8.58E-10		H(20)/H(1) --->	1.57	8.47E-10		H(100)/H(1) --->	1.57	8.46E-10	
66	2.43	1.14			2.93	1.38			3.17	1.49			3.33	1.57		
67	1.00	0.13			1.00	0.13			0.38	0.05			0.00	0.00		
68	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
69	H(5)/H(1) --->	1.42	1.56E-09		H(10)/H(1) --->	1.59	1.75E-09		H(20)/H(1) --->	1.57	1.73E-09		H(100)/H(1) --->	1.57	1.72E-09	
71			**1.22E-08**	**1.41E+00**			**1.37E-08**	**1.57E+00**			**1.35E-08**	**1.55E+00**			**1.35E-08**	**1.55E+00**

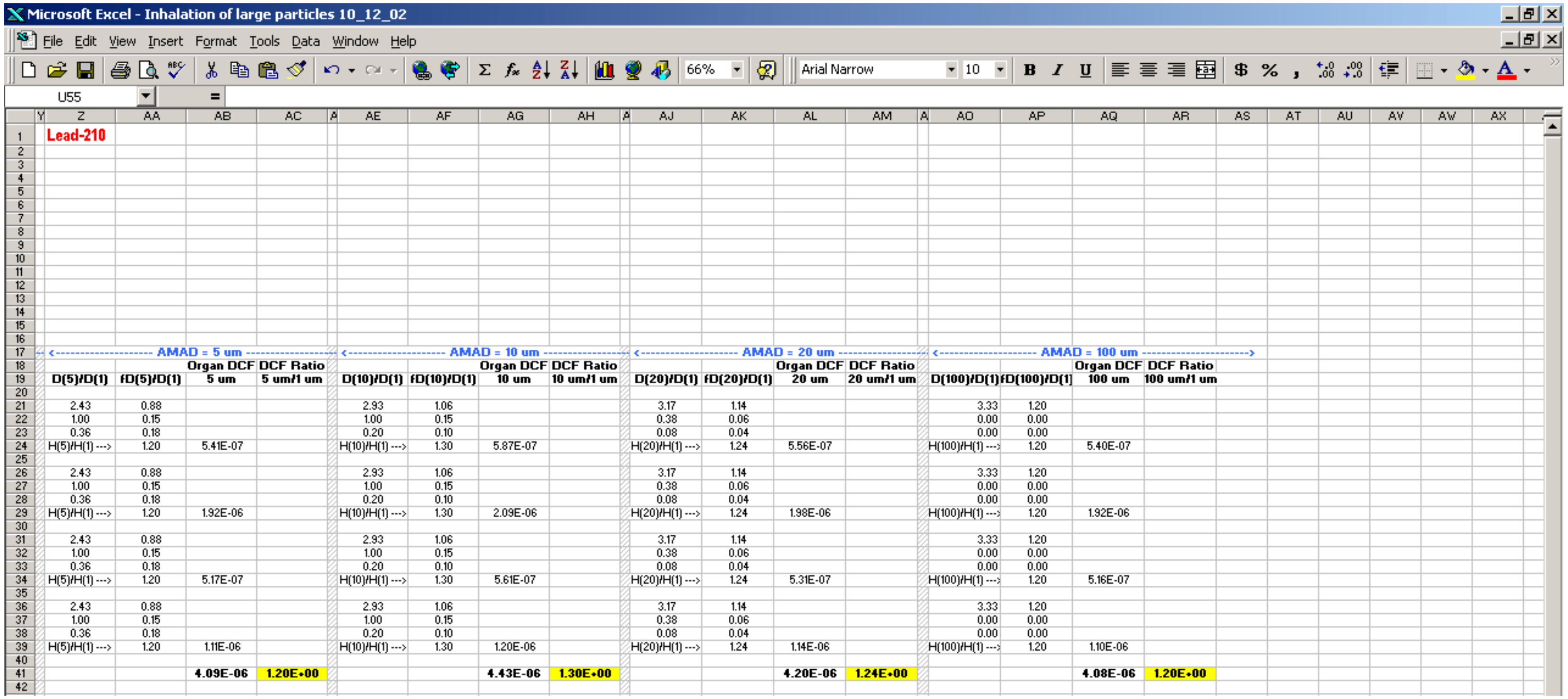
Figure II-8b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Cesium-137

Microsoft Excel - Inhalation of large particles 10_12_02

A	B	C	D	E	F	G	H	I	K	L
Lead-210										
Class D										
D(0.1)	**D(0.2)**	**D(0.5)**	**D(1)**	**D(2)**	**D(5)**	**D(10)**	**D(20)**	**D(100)**		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
D(0.2)/D(1)	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

				<------ AMAD = 0.1 um ------				<------ AMAD = 0.2 um ------				<------ AMAD = 0.5 um ------				<------ AMAD = 2 um ------			
Organ	**Organ DCF 1 um**	**Region**	**f**	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**Organ DCF 0.1 um**	**DCF Ratio 0.1 um/1 um**	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**Organ DCF 0.2 um**	**DCF Ratio 0.2 um/1 um**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**Organ DCF 0.5 um**	**DCF Ratio 0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**Organ DCF 2 um**	**DCF Ratio 2 um/1 um**
R Marrow		N-P	0.36	0.33	0.12			0.17	0.06			0.57	0.20			1.60	0.58		
		T-B	0.15	2.50	0.38			1.00	0.15			1.00	0.15			1.00	0.15		
		P	0.49	2.40	1.18			2.00	0.98			1.40	0.69			0.68	0.33		
	4.50E-07			H(0.1)/H(1) --->	1.67	7.52E-07		H(0.2)/H(1) --->	1.19	5.36E-07		H(0.5)/H(1) --->	1.04	4.68E-07		H(2)/H(1) --->	1.06	4.77E-07	
Bone Surf		N-P	0.36	0.33	0.12			0.17	0.06			0.57	0.20			1.60	0.58		
		T-B	0.15	2.50	0.38			1.00	0.15			1.00	0.15			1.00	0.15		
		P	0.49	2.40	1.18			2.00	0.98			1.40	0.69			0.68	0.33		
	1.60E-06			H(0.1)/H(1) --->	1.67	2.67E-06		H(0.2)/H(1) --->	1.19	1.90E-06		H(0.5)/H(1) --->	1.04	1.66E-06		H(2)/H(1) --->	1.06	1.69E-06	
Kidneys		N-P	0.36	0.33	0.12			0.17	0.06			0.57	0.20			1.60	0.58		
		T-B	0.15	2.50	0.38			1.00	0.15			1.00	0.15			1.00	0.15		
		P	0.49	2.40	1.18			2.00	0.98			1.40	0.69			0.68	0.33		
	4.30E-07			H(0.1)/H(1) --->	1.67	7.19E-07		H(0.2)/H(1) --->	1.19	5.12E-07		H(0.5)/H(1) --->	1.04	4.47E-07		H(2)/H(1) --->	1.06	4.55E-07	
Liver		N-P	0.36	0.33	0.12			0.17	0.06			0.57	0.20			1.60	0.58		
		T-B	0.15	2.50	0.38			1.00	0.15			1.00	0.15			1.00	0.15		
		P	0.49	2.40	1.18			2.00	0.98			1.40	0.69			0.68	0.33		
	9.20E-07			H(0.1)/H(1) --->	1.67	1.54E-06		H(0.2)/H(1) --->	1.19	1.09E-06		H(0.5)/H(1) --->	1.04	9.57E-07		H(2)/H(1) --->	1.06	9.74E-07	
Sum	**3.40E-06**					**5.68E-06**	**1.67E+00**			**4.05E-06**	**1.19E+00**			**3.54E-06**	**1.04E+00**			**3.60E-06**	**1.06E+00**

Figure II-9a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Lead-210



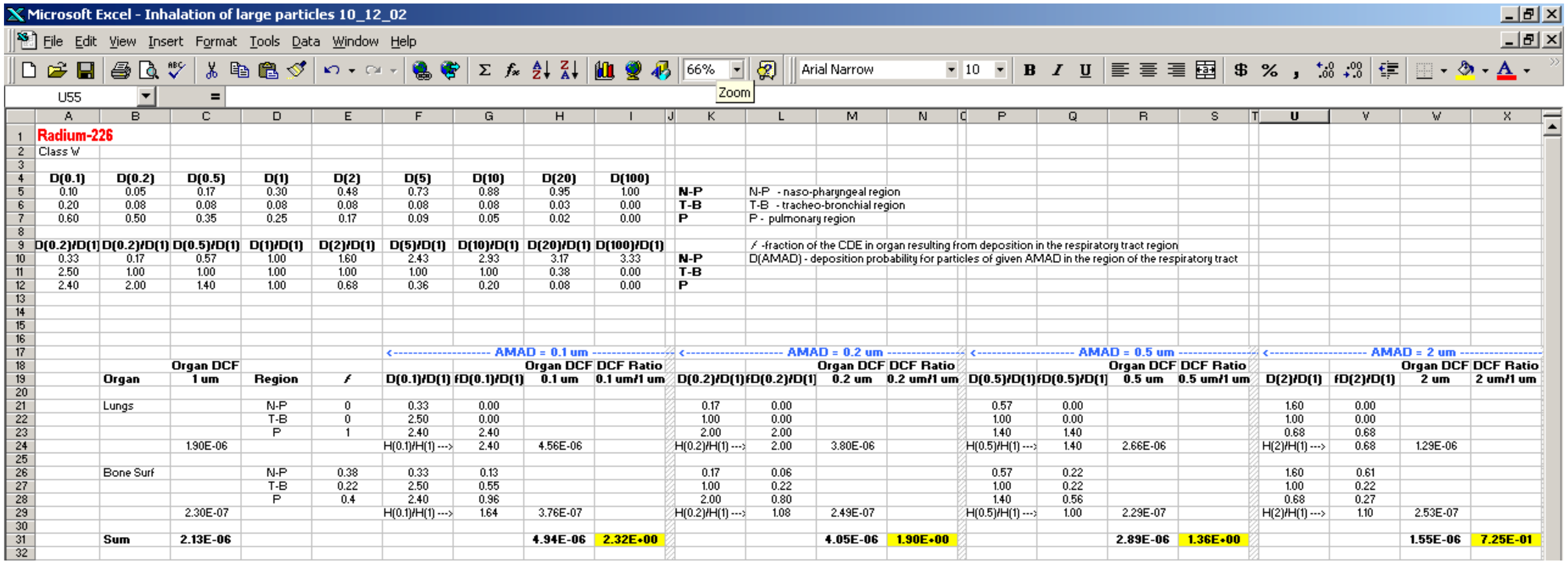
Microsoft Excel - Inhalation of large particles 10_12_02

Lead-210

Row	D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
17	<-------- AMAD = 5 um --------				<-------- AMAD = 10 um --------			
21	2.43	0.88			2.93	1.06		
22	1.00	0.15			1.00	0.15		
23	0.36	0.18			0.20	0.10		
24	H(5)/H(1) --->	1.20	5.41E-07		H(10)/H(1) --->	1.30	5.87E-07	
26	2.43	0.88			2.93	1.06		
27	1.00	0.15			1.00	0.15		
28	0.36	0.18			0.20	0.10		
29	H(5)/H(1) --->	1.20	1.92E-06		H(10)/H(1) --->	1.30	2.09E-06	
31	2.43	0.88			2.93	1.06		
32	1.00	0.15			1.00	0.15		
33	0.36	0.18			0.20	0.10		
34	H(5)/H(1) --->	1.20	5.17E-07		H(10)/H(1) --->	1.30	5.61E-07	
36	2.43	0.88			2.93	1.06		
37	1.00	0.15			1.00	0.15		
38	0.36	0.18			0.20	0.10		
39	H(5)/H(1) --->	1.20	1.11E-06		H(10)/H(1) --->	1.30	1.20E-06	
41			**4.09E-06**	**1.20E+00**			**4.43E-06**	**1.30E+00**

Row	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
17	<-------- AMAD = 20 um --------				<-------- AMAD = 100 um -------->			
21	3.17	1.14			3.33	1.20		
22	0.38	0.06			0.00	0.00		
23	0.08	0.04			0.00	0.00		
24	H(20)/H(1) --->	1.24	5.56E-07		H(100)/H(1) --->	1.20	5.40E-07	
26	3.17	1.14			3.33	1.20		
27	0.38	0.06			0.00	0.00		
28	0.08	0.04			0.00	0.00		
29	H(20)/H(1) --->	1.24	1.98E-06		H(100)/H(1) --->	1.20	1.92E-06	
31	3.17	1.14			3.33	1.20		
32	0.38	0.06			0.00	0.00		
33	0.08	0.04			0.00	0.00		
34	H(20)/H(1) --->	1.24	5.31E-07		H(100)/H(1) --->	1.20	5.16E-07	
36	3.17	1.14			3.33	1.20		
37	0.38	0.06			0.00	0.00		
38	0.08	0.04			0.00	0.00		
39	H(20)/H(1) --->	1.24	1.14E-06		H(100)/H(1) --->	1.20	1.10E-06	
41			**4.20E-06**	**1.24E+00**			**4.08E-06**	**1.20E+00**

Figure II-9b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Lead-210



Microsoft Excel - Inhalation of large particles 10_12_02

Radium-226

Class W

Row	A	B	C	D	E	F	G	H	I	K
4	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
5	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	N-P
6	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	T-B
7	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	P
9	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
10	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	N-P
11	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	T-B
12	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	P

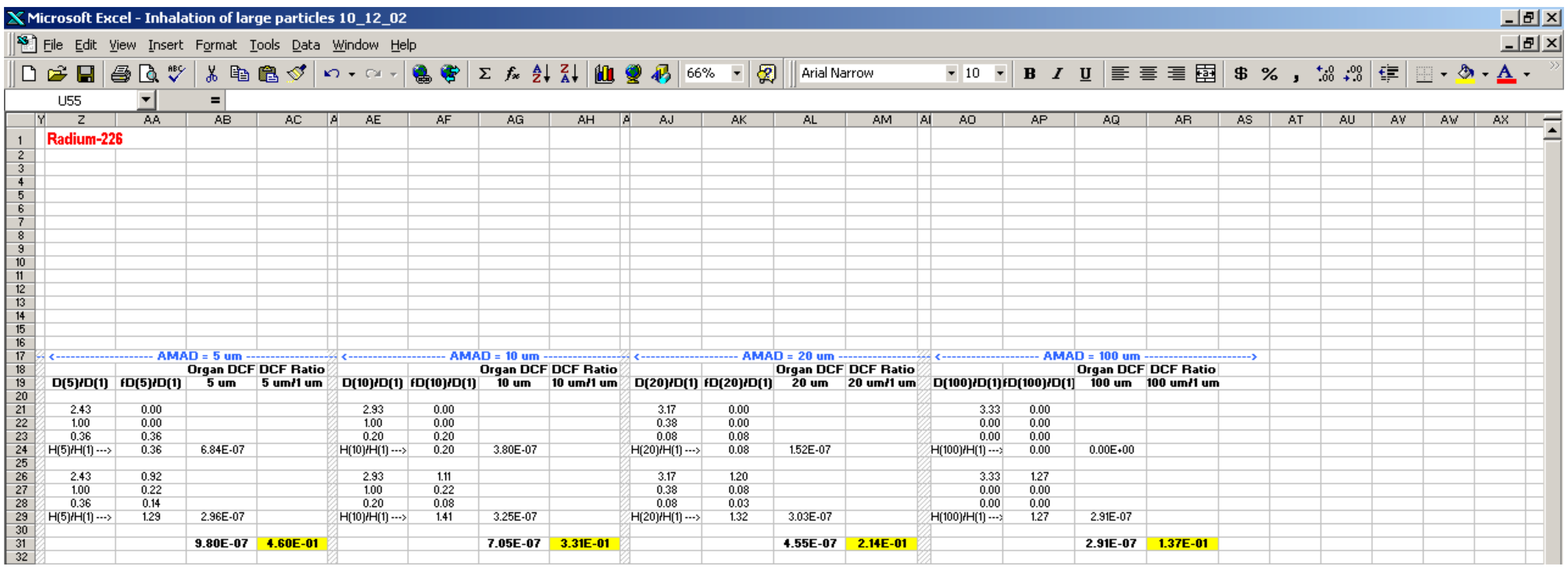
N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

<----- AMAD = 0.1 um ----->

Row	Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
21	Lungs		N-P	0	0.33	0.00		
22			T-B	0	2.50	0.00		
23			P	1	2.40	2.40		
24		1.90E-06			H(0.1)/H(1) --->	2.40	4.56E-06	
26	Bone Surf		N-P	0.38	0.33	0.13		
27			T-B	0.22	2.50	0.55		
28			P	0.4	2.40	0.96		
29		2.30E-07			H(0.1)/H(1) --->	1.64	3.76E-07	
31	Sum	2.13E-06					4.94E-06	2.32E+00

Row	AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
21	0.17	0.00			0.57	0.00			1.60	0.00		
22	1.00	0.00			1.00	0.00			1.00	0.00		
23	2.00	2.00			1.40	1.40			0.68	0.68		
24	H(0.2)/H(1) --->	2.00	3.80E-06		H(0.5)/H(1) --->	1.40	2.66E-06		H(2)/H(1) --->	0.68	1.29E-06	
26	0.17	0.06			0.57	0.22			1.60	0.61		
27	1.00	0.22			1.00	0.22			1.00	0.22		
28	2.00	0.80			1.40	0.56			0.68	0.27		
29	H(0.2)/H(1) --->	1.08	2.49E-07		H(0.5)/H(1) --->	1.00	2.29E-07		H(2)/H(1) --->	1.10	2.53E-07	
31			4.05E-06	1.90E+00			2.89E-06	1.36E+00			1.55E-06	7.25E-01



Microsoft Excel - Inhalation of large particles 10_12_02

Radium-226

Row	AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
21	2.43	0.00			2.93	0.00			3.17	0.00			3.33	0.00		
22	1.00	0.00			1.00	0.00			0.38	0.00			0.00	0.00		
23	0.36	0.36			0.20	0.20			0.08	0.08			0.00	0.00		
24	H(5)/H(1) --->	0.36	6.84E-07		H(10)/H(1) --->	0.20	3.80E-07		H(20)/H(1) --->	0.08	1.52E-07		H(100)/H(1) --->	0.00	0.00E+00	
26	2.43	0.92			2.93	1.11			3.17	1.20			3.33	1.27		
27	1.00	0.22			1.00	0.22			0.38	0.08			0.00	0.00		
28	0.36	0.14			0.20	0.08			0.08	0.03			0.00	0.00		
29	H(5)/H(1) --->	1.29	2.96E-07		H(10)/H(1) --->	1.41	3.25E-07		H(20)/H(1) --->	1.32	3.03E-07		H(100)/H(1) --->	1.27	2.91E-07	
31			9.80E-07	4.60E-01			7.05E-07	3.31E-01			4.55E-07	2.14E-01			2.91E-07	1.37E-01

Figure II-10. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Radium-226

Microsoft Excel - Inhalation of large particles 10_12_02

Actinium-227

Class D

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)		*f* -fraction of the CDE in organ resulting from deposition in the respiratory tract region
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

AMAD = 0.1 um

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Gonads		N-P	0.32	0.33	0.11		
		T-B	0.16	2.50	0.40		
		P	0.52	2.40	1.25		
	9.90E-05			H(0.1)/H(1) --->	1.75	1.74E-04	
R Marrow		N-P	0.32	0.33	0.11		
		T-B	0.16	2.50	0.40		
		P	0.52	2.40	1.25		
	3.10E-04			H(0.1)/H(1) --->	1.75	5.44E-04	
Bone Surf		N-P	0.32	0.33	0.11		
		T-B	0.16	2.50	0.40		
		P	0.52	2.40	1.25		
	9.60E-04			H(0.1)/H(1) --->	1.75	1.68E-03	
Liver		N-P	0.32	0.33	0.11		
		T-B	0.16	2.50	0.40		
		P	0.52	2.40	1.25		
	4.40E-04			H(0.1)/H(1) --->	1.75	7.72E-04	
Sum	**1.81E-03**					**3.17E-03**	**1.75E+00**

AMAD = 0.2 um

Organ	Region	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads	N-P	0.17	0.05		
	T-B	1.00	0.16		
	P	2.00	1.04		
		H(0.2)/H(1) --->	1.25	1.24E-04	
R Marrow	N-P	0.17	0.05		
	T-B	1.00	0.16		
	P	2.00	1.04		
		H(0.2)/H(1) --->	1.25	3.89E-04	
Bone Surf	N-P	0.17	0.05		
	T-B	1.00	0.16		
	P	2.00	1.04		
		H(0.2)/H(1) --->	1.25	1.20E-03	
Liver	N-P	0.17	0.05		
	T-B	1.00	0.16		
	P	2.00	1.04		
		H(0.2)/H(1) --->	1.25	5.51E-04	
Sum				**2.27E-03**	**1.25E+00**

AMAD = 0.5 um

Organ	Region	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
Gonads	N-P	0.57	0.18		
	T-B	1.00	0.16		
	P	1.40	0.73		
		H(0.5)/H(1) --->	1.07	1.06E-04	
R Marrow	N-P	0.57	0.18		
	T-B	1.00	0.16		
	P	1.40	0.73		
		H(0.5)/H(1) --->	1.07	3.31E-04	
Bone Surf	N-P	0.57	0.18		
	T-B	1.00	0.16		
	P	1.40	0.73		
		H(0.5)/H(1) --->	1.07	1.03E-03	
Liver	N-P	0.57	0.18		
	T-B	1.00	0.16		
	P	1.40	0.73		
		H(0.5)/H(1) --->	1.07	4.71E-04	
Sum				**1.93E-03**	**1.07E+00**

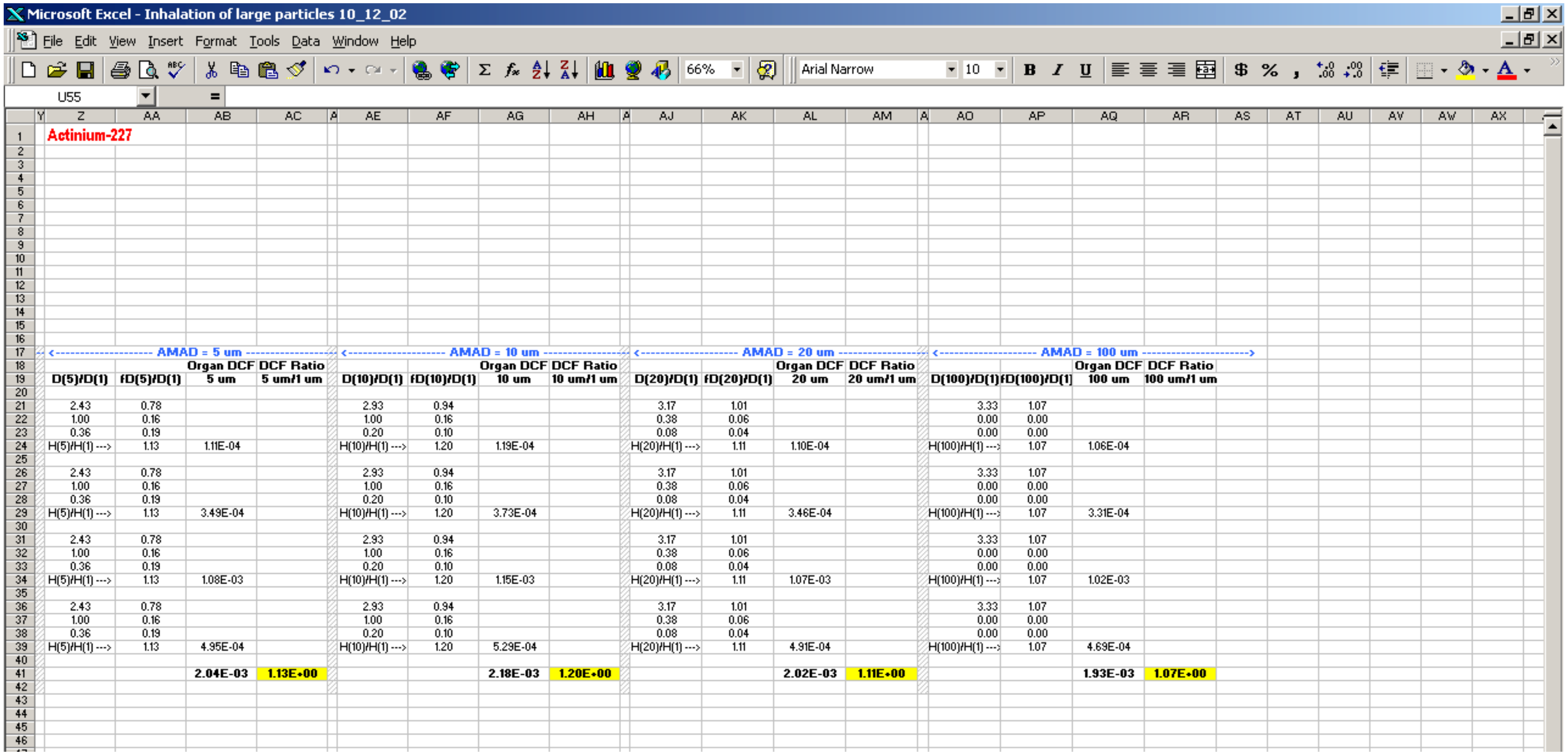
AMAD = 2 um

Organ	Region	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	N-P	1.60	0.51		
	T-B	1.00	0.16		
	P	0.68	0.35		
		H(2)/H(1) --->	1.03	1.02E-04	
R Marrow	N-P	1.60	0.51		
	T-B	1.00	0.16		
	P	0.68	0.35		
		H(2)/H(1) --->	1.03	3.18E-04	
Bone Surf	N-P	1.60	0.51		
	T-B	1.00	0.16		
	P	0.68	0.35		
		H(2)/H(1) --->	1.03	9.85E-04	
Liver	N-P	1.60	0.51		
	T-B	1.00	0.16		
	P	0.68	0.35		
		H(2)/H(1) --->	1.03	4.51E-04	
Sum				**1.86E-03**	**1.03E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\,\mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\,\mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\,\mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\,\mu m)}$$

H 50 - committed dose equivalent in organ/tissue

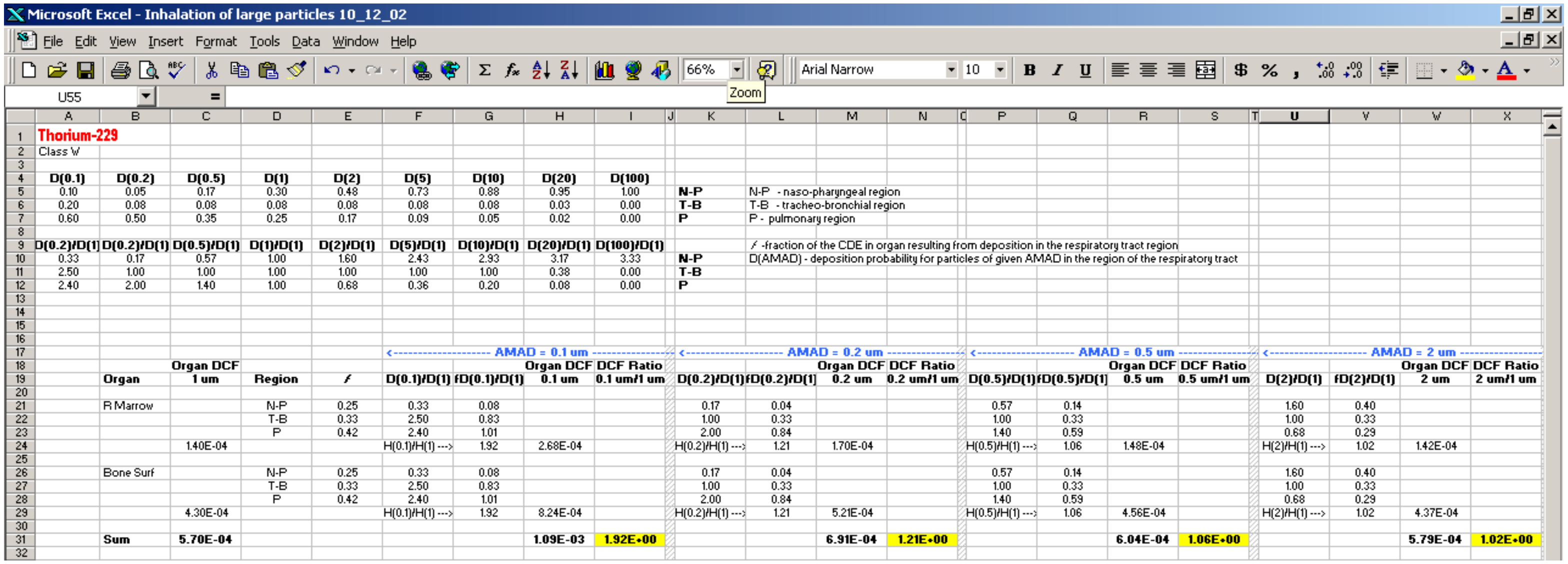
Figure II-11a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Actinium-227



Actinium-227

Row	D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
17	<------------------ AMAD = 5 um ------------------				<------------------ AMAD = 10 um ------------------				<------------------ AMAD = 20 um ------------------				<------------------ AMAD = 100 um ------------------>			
21	2.43	0.78			2.93	0.94			3.17	1.01			3.33	1.07		
22	1.00	0.16			1.00	0.16			0.38	0.06			0.00	0.00		
23	0.36	0.19			0.20	0.10			0.08	0.04			0.00	0.00		
24	H(5)/H(1) --->	1.13	1.11E-04		H(10)/H(1) --->	1.20	1.19E-04		H(20)/H(1) --->	1.11	1.10E-04		H(100)/H(1) --->	1.07	1.06E-04	
26	2.43	0.78			2.93	0.94			3.17	1.01			3.33	1.07		
27	1.00	0.16			1.00	0.16			0.38	0.06			0.00	0.00		
28	0.36	0.19			0.20	0.10			0.08	0.04			0.00	0.00		
29	H(5)/H(1) --->	1.13	3.49E-04		H(10)/H(1) --->	1.20	3.73E-04		H(20)/H(1) --->	1.11	3.46E-04		H(100)/H(1) --->	1.07	3.31E-04	
31	2.43	0.78			2.93	0.94			3.17	1.01			3.33	1.07		
32	1.00	0.16			1.00	0.16			0.38	0.06			0.00	0.00		
33	0.36	0.19			0.20	0.10			0.08	0.04			0.00	0.00		
34	H(5)/H(1) --->	1.13	1.08E-03		H(10)/H(1) --->	1.20	1.15E-03		H(20)/H(1) --->	1.11	1.07E-03		H(100)/H(1) --->	1.07	1.02E-03	
36	2.43	0.78			2.93	0.94			3.17	1.01			3.33	1.07		
37	1.00	0.16			1.00	0.16			0.38	0.06			0.00	0.00		
38	0.36	0.19			0.20	0.10			0.08	0.04			0.00	0.00		
39	H(5)/H(1) --->	1.13	4.95E-04		H(10)/H(1) --->	1.20	5.29E-04		H(20)/H(1) --->	1.11	4.91E-04		H(100)/H(1) --->	1.07	4.69E-04	
41			**2.04E-03**	**1.13E+00**			**2.18E-03**	**1.20E+00**			**2.02E-03**	**1.11E+00**			**1.93E-03**	**1.07E+00**

Figure II-11b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Actinium-227



Microsoft Excel - Inhalation of large particles 10_12_02

Thorium-229

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	N-P
	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	T-B
	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	P

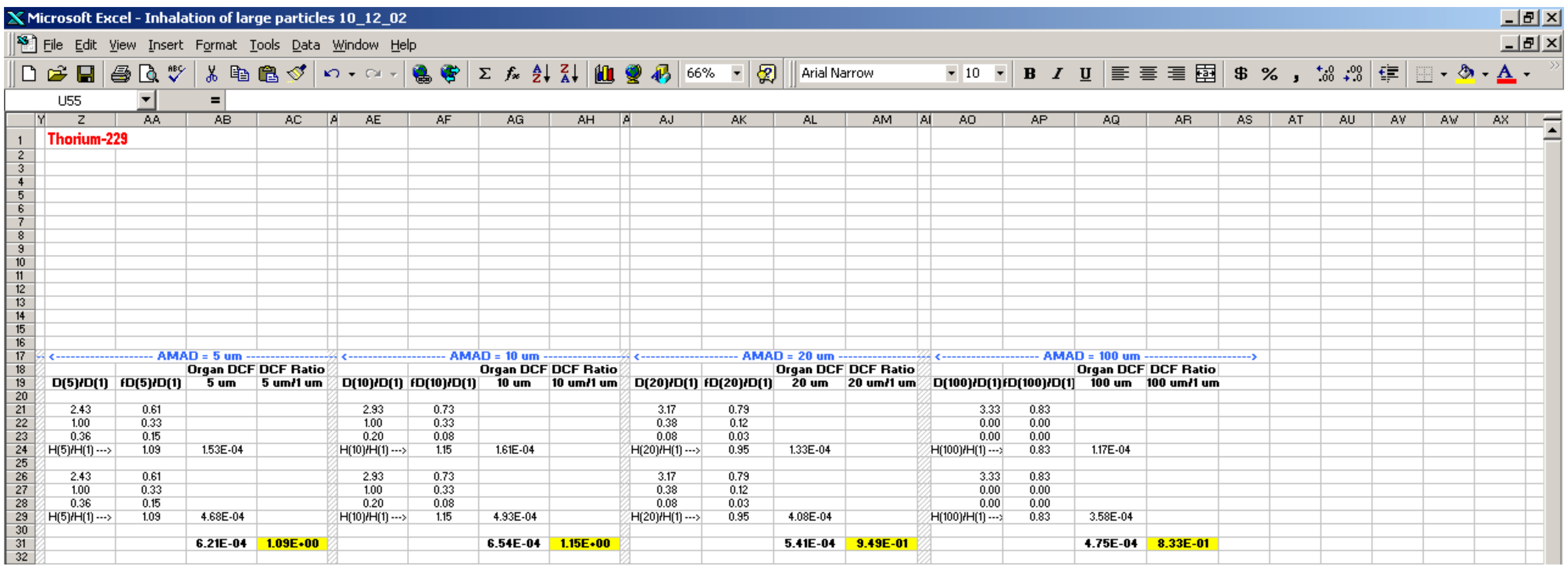
	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	N-P
	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	T-B
	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	P

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	1.40E-04			H(0.1)/H(1) --->	1.92	2.68E-04	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	4.30E-04			H(0.1)/H(1) --->	1.92	8.24E-04	
Sum	5.70E-04					1.09E-03	1.92E+00

AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	1.70E-04		H(0.5)/H(1) --->	1.06	1.48E-04		H(2)/H(1) --->	1.02	1.42E-04	
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	5.21E-04		H(0.5)/H(1) --->	1.06	4.56E-04		H(2)/H(1) --->	1.02	4.37E-04	
		6.91E-04	1.21E+00			6.04E-04	1.06E+00			5.79E-04	1.02E+00

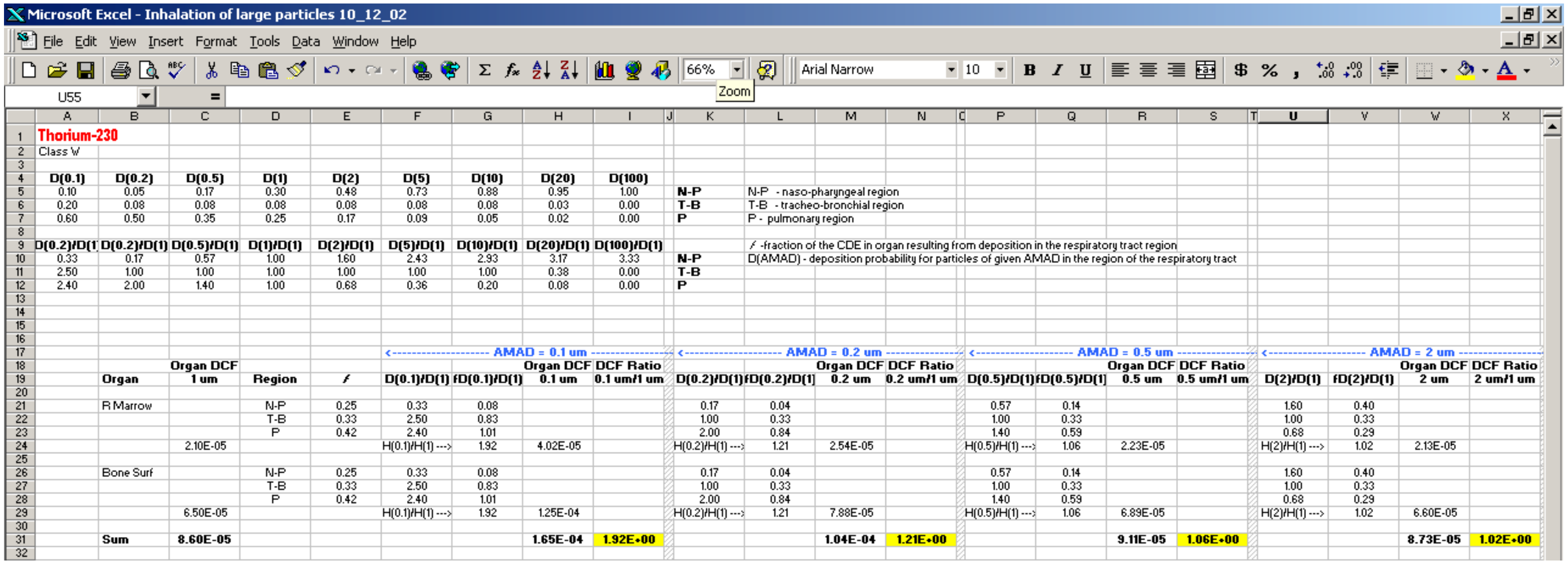


Microsoft Excel - Inhalation of large particles 10_12_02

Thorium-229

AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	1.53E-04		H(10)/H(1) --->	1.15	1.61E-04		H(20)/H(1) --->	0.95	1.33E-04		H(100)/H(1) --->	0.83	1.17E-04	
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	4.68E-04		H(10)/H(1) --->	1.15	4.93E-04		H(20)/H(1) --->	0.95	4.08E-04		H(100)/H(1) --->	0.83	3.58E-04	
		6.21E-04	1.09E+00			6.54E-04	1.15E+00			5.41E-04	9.49E-01			4.75E-04	8.33E-01

Figure II-12. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Thorium-229



Microsoft Excel - Inhalation of large particles 10_12_02

Thorium-230

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

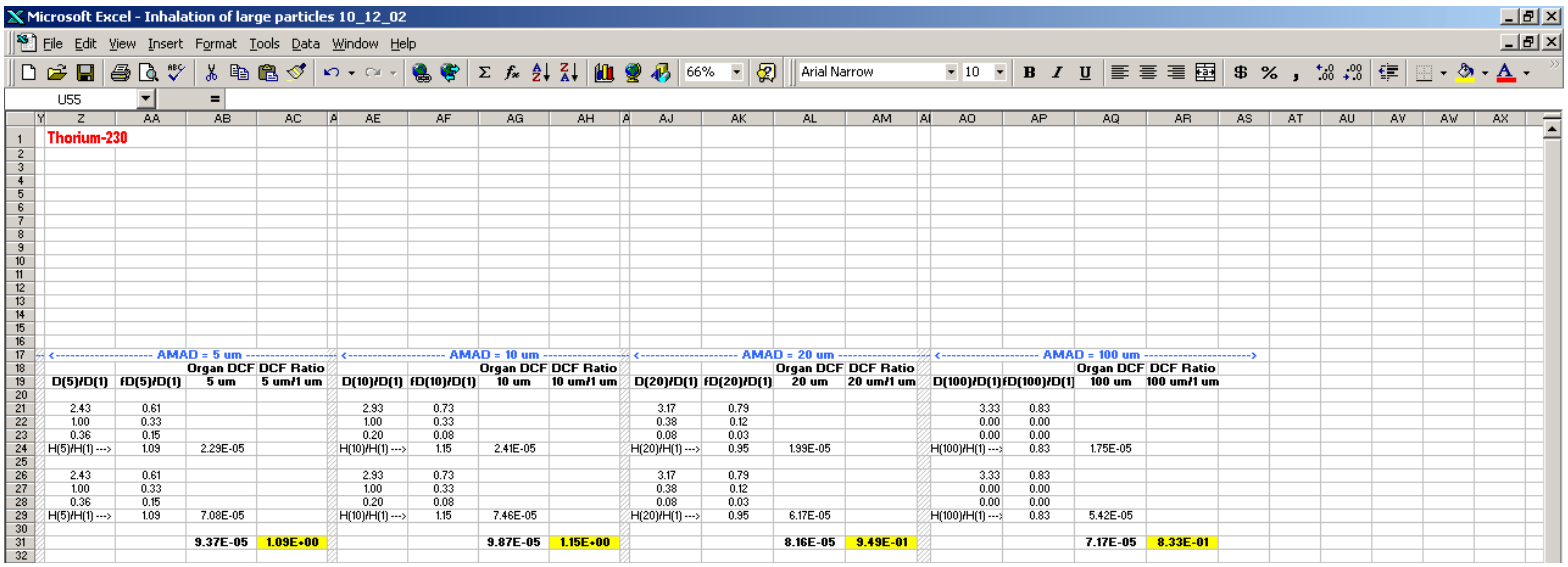
	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.10E-05			H(0.1)/H(1) --->	1.92	4.02E-05	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	6.50E-05			H(0.1)/H(1) --->	1.92	1.25E-04	
Sum	8.60E-05					1.65E-04	1.92E+00

AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	2.54E-05		H(0.5)/H(1) --->	1.06	2.23E-05		H(2)/H(1) --->	1.02	2.13E-05	
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	7.88E-05		H(0.5)/H(1) --->	1.06	6.89E-05		H(2)/H(1) --->	1.02	6.60E-05	
		1.04E-04	1.21E+00			9.11E-05	1.06E+00			8.73E-05	1.02E+00



Microsoft Excel - Inhalation of large particles 10_12_02

Thorium-230

AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	2.29E-05		H(10)/H(1) --->	1.15	2.41E-05		H(20)/H(1) --->	0.95	1.99E-05		H(100)/H(1) --->	0.83	1.75E-05	
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	7.08E-05		H(10)/H(1) --->	1.15	7.46E-05		H(20)/H(1) --->	0.95	6.17E-05		H(100)/H(1) --->	0.83	5.42E-05	
		9.37E-05	1.09E+00			9.87E-05	1.15E+00			8.16E-05	9.49E-01			7.17E-05	8.33E-01

Figure II-13. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Thorium-230

Microsoft Excel - Inhalation of large particles 10_12_02

Row	A	B	C	D	E	F	G	H	I	K	L
1	**Thorium-232**										
2	Class W										
3											
4	**D(0.1)**	**D(0.2)**	**D(0.5)**	**D(1)**	**D(2)**	**D(5)**	**D(10)**	**D(20)**	**D(100)**		
5	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
6	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
7	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
8											
9	**D(0.2)/D(1**	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
10	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
11	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
12	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

Row	B	C	D	E	F	G	H	I
17					<------ AMAD = 0.1 um ------			
18		**Organ DCF**					**Organ DCF**	**DCF Ratio**
19	**Organ**	**1 um**	**Region**	**f**	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**0.1 um**	**0.1 um/1 um**
21	R Marrow		N-P	0.25	0.33	0.08		
22			T-B	0.33	2.50	0.83		
23			P	0.42	2.40	1.01		
24		1.10E-04			H(0.1)/H(1) --->	1.92	2.11E-04	
26	Bone Surf		N-P	0.25	0.33	0.08		
27			T-B	0.33	2.50	0.83		
28			P	0.42	2.40	1.01		
29		3.30E-04			H(0.1)/H(1) --->	1.92	6.32E-04	
31	**Sum**	**4.40E-04**					**8.43E-04**	**1.92E+00**

Row	K	L	M	N
17	<------ AMAD = 0.2 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**0.2 um**	**0.2 um/1 um**
21	0.17	0.04		
22	1.00	0.33		
23	2.00	0.84		
24	H(0.2)/H(1) --->	1.21	1.33E-04	
26	0.17	0.04		
27	1.00	0.33		
28	2.00	0.84		
29	H(0.2)/H(1) --->	1.21	4.00E-04	
31			**5.33E-04**	**1.21E+00**

Row	P	Q	R	S
17	<------ AMAD = 0.5 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**0.5 um**	**0.5 um/1 um**
21	0.57	0.14		
22	1.00	0.33		
23	1.40	0.59		
24	H(0.5)/H(1) --->	1.06	1.17E-04	
26	0.57	0.14		
27	1.00	0.33		
28	1.40	0.59		
29	H(0.5)/H(1) --->	1.06	3.50E-04	
31			**4.66E-04**	**1.06E+00**

Row	U	V	W	X
17	<------ AMAD = 2 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(2)/D(1)**	**fD(2)/D(1)**	**2 um**	**2 um/1 um**
21	1.60	0.40		
22	1.00	0.33		
23	0.68	0.29		
24	H(2)/H(1) --->	1.02	1.12E-04	
26	1.60	0.40		
27	1.00	0.33		
28	0.68	0.29		
29	H(2)/H(1) --->	1.02	3.35E-04	
31			**4.47E-04**	**1.02E+00**

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Thorium-232

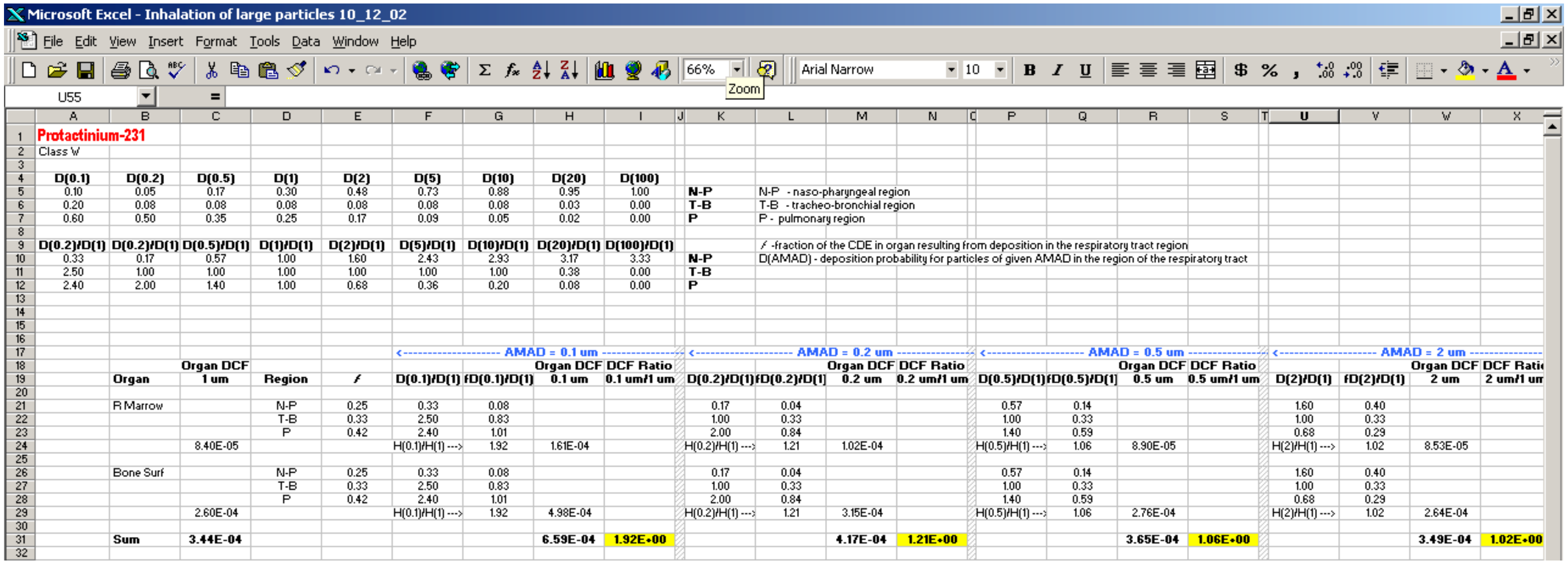
Row	Z	AA	AB	AC
17	<------ AMAD = 5 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(5)/D(1)**	**fD(5)/D(1)**	**5 um**	**5 um/1 um**
21	2.43	0.61		
22	1.00	0.33		
23	0.36	0.15		
24	H(5)/H(1) --->	1.09	1.20E-04	
26	2.43	0.61		
27	1.00	0.33		
28	0.36	0.15		
29	H(5)/H(1) --->	1.09	3.60E-04	
31			**4.79E-04**	**1.09E+00**

Row	AE	AF	AG	AH
17	<------ AMAD = 10 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(10)/D(1)**	**fD(10)/D(1)**	**10 um**	**10 um/1 um**
21	2.93	0.73		
22	1.00	0.33		
23	0.20	0.08		
24	H(10)/H(1) --->	1.15	1.26E-04	
26	2.93	0.73		
27	1.00	0.33		
28	0.20	0.08		
29	H(10)/H(1) --->	1.15	3.79E-04	
31			**5.05E-04**	**1.15E+00**

Row	AJ	AK	AL	AM
17	<------ AMAD = 20 um ------			
18			**Organ DCF**	**DCF Ratio**
19	**D(20)/D(1)**	**fD(20)/D(1)**	**20 um**	**20 um/1 um**
21	3.17	0.79		
22	0.38	0.12		
23	0.08	0.03		
24	H(20)/H(1) --->	0.95	1.04E-04	
26	3.17	0.79		
27	0.38	0.12		
28	0.08	0.03		
29	H(20)/H(1) --->	0.95	3.13E-04	
31			**4.18E-04**	**9.49E-01**

Row	AO	AP	AQ	AR
17	<------ AMAD = 100 um ------>			
18			**Organ DCF**	**DCF Ratio**
19	**D(100)/D(1)**	**fD(100)/D(1)**	**100 um**	**100 um/1 um**
21	3.33	0.83		
22	0.00	0.00		
23	0.00	0.00		
24	H(100)/H(1) --->	0.83	9.17E-05	
26	3.33	0.83		
27	0.00	0.00		
28	0.00	0.00		
29	H(100)/H(1) --->	0.83	2.75E-04	
31			**3.67E-04**	**8.33E-01**

Figure II-14. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Thorium-232



Microsoft Excel - Inhalation of large particles 10_12_02

Protactinium-231

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	N-P
	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	T-B
	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	P

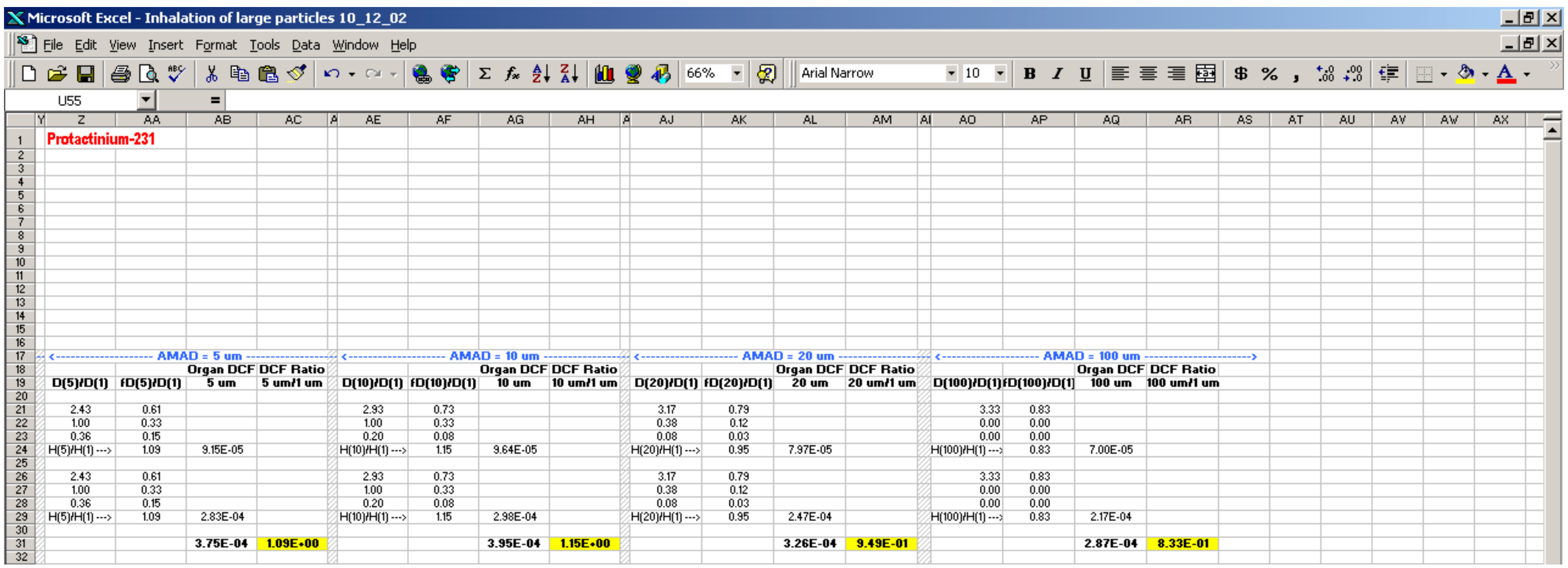
	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	N-P
	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	T-B
	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	P

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	f	AMAD = 0.1 um: D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	8.40E-05			H(0.1)/H(1) --->	1.92	1.61E-04	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.60E-04			H(0.1)/H(1) --->	1.92	4.98E-04	
Sum	3.44E-04					6.59E-04	1.92E+00

AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	1.02E-04		H(0.5)/H(1) --->	1.06	8.90E-05		H(2)/H(1) --->	1.02	8.53E-05	
0.17	0.04			0.57	0.14			1.60	0.40		
1.00	0.33			1.00	0.33			1.00	0.33		
2.00	0.84			1.40	0.59			0.68	0.29		
H(0.2)/H(1) --->	1.21	3.15E-04		H(0.5)/H(1) --->	1.06	2.76E-04		H(2)/H(1) --->	1.02	2.64E-04	
		4.17E-04	1.21E+00			3.65E-04	1.06E+00			3.49E-04	1.02E+00



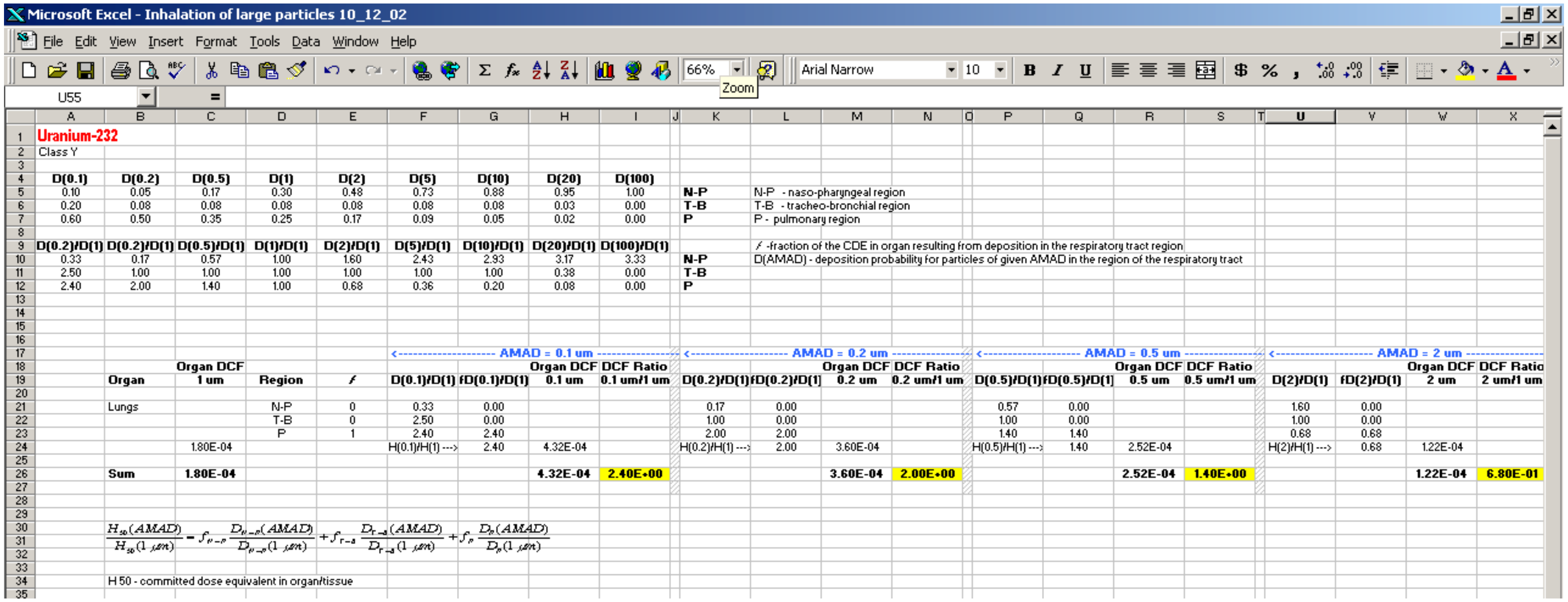
Microsoft Excel - Inhalation of large particles 10_12_02

Protactinium-231

AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.43	0.61			2.93	0.73		
1.00	0.33			1.00	0.33		
0.36	0.15			0.20	0.08		
H(5)/H(1) --->	1.09	9.15E-05		H(10)/H(1) --->	1.15	9.64E-05	
2.43	0.61			2.93	0.73		
1.00	0.33			1.00	0.33		
0.36	0.15			0.20	0.08		
H(5)/H(1) --->	1.09	2.83E-04		H(10)/H(1) --->	1.15	2.98E-04	
		3.75E-04	1.09E+00			3.95E-04	1.15E+00

AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.17	0.79			3.33	0.83		
0.38	0.12			0.00	0.00		
0.08	0.03			0.00	0.00		
H(20)/H(1) --->	0.95	7.97E-05		H(100)/H(1) --->	0.83	7.00E-05	
3.17	0.79			3.33	0.83		
0.38	0.12			0.00	0.00		
0.08	0.03			0.00	0.00		
H(20)/H(1) --->	0.95	2.47E-04		H(100)/H(1) --->	0.83	2.17E-04	
		3.26E-04	9.49E-01			2.87E-04	8.33E-01

Figure II-15. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 µm Particles for Protactinium-231



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-232

Class Y

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*
Lungs		N-P	0
		T-B	0
		P	1
	1.80E-04		
Sum	1.80E-04		

AMAD = 0.1 um

D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
0.33	0.00		
2.50	0.00		
2.40	2.40		
H(0.1)/H(1) --->	2.40	4.32E-04	
		4.32E-04	2.40E+00

AMAD = 0.2 um

D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
0.17	0.00		
1.00	0.00		
2.00	2.00		
H(0.2)/H(1) --->	2.00	3.60E-04	
		3.60E-04	2.00E+00

AMAD = 0.5 um

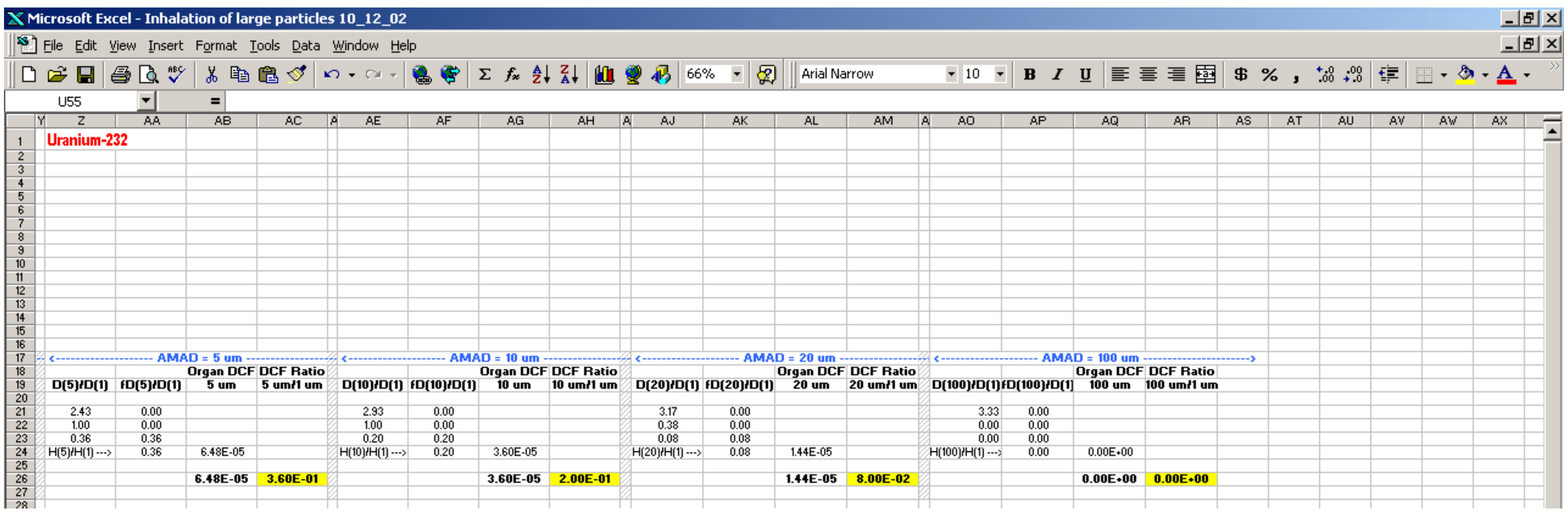
D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
0.57	0.00		
1.00	0.00		
1.40	1.40		
H(0.5)/H(1) --->	1.40	2.52E-04	
		2.52E-04	1.40E+00

AMAD = 2 um

D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
1.60	0.00		
1.00	0.00		
0.68	0.68		
H(2)/H(1) --->	0.68	1.22E-04	
		1.22E-04	6.80E-01

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-232

AMAD = 5 um

D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
2.43	0.00		
1.00	0.00		
0.36	0.36		
H(5)/H(1) --->	0.36	6.48E-05	
		6.48E-05	3.60E-01

AMAD = 10 um

D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.93	0.00		
1.00	0.00		
0.20	0.20		
H(10)/H(1) --->	0.20	3.60E-05	
		3.60E-05	2.00E-01

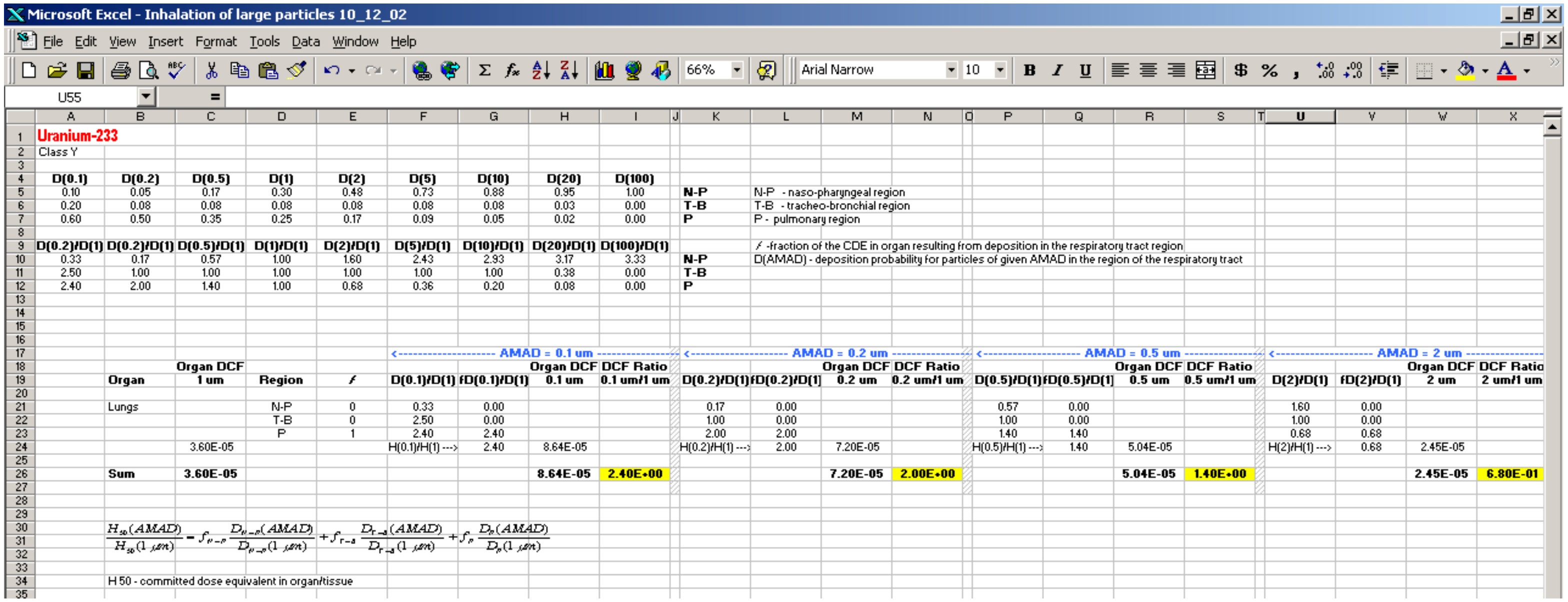
AMAD = 20 um

D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
3.17	0.00		
0.38	0.00		
0.08	0.08		
H(20)/H(1) --->	0.08	1.44E-05	
		1.44E-05	8.00E-02

AMAD = 100 um

D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.33	0.00		
0.00	0.00		
0.00	0.00		
H(100)/H(1) --->	0.00	0.00E+00	
		0.00E+00	0.00E+00

Figure II-16. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 µm Particles for Uranium-232



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-233

Class Y

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*
Lungs		N-P	0
		T-B	0
		P	1
	3.60E-05		
Sum	**3.60E-05**		

	AMAD = 0.1 um			
	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
N-P	0.33	0.00		
T-B	2.50	0.00		
P	2.40	2.40		
	H(0.1)/H(1) --->	2.40	8.64E-05	
Sum			**8.64E-05**	**2.40E+00**

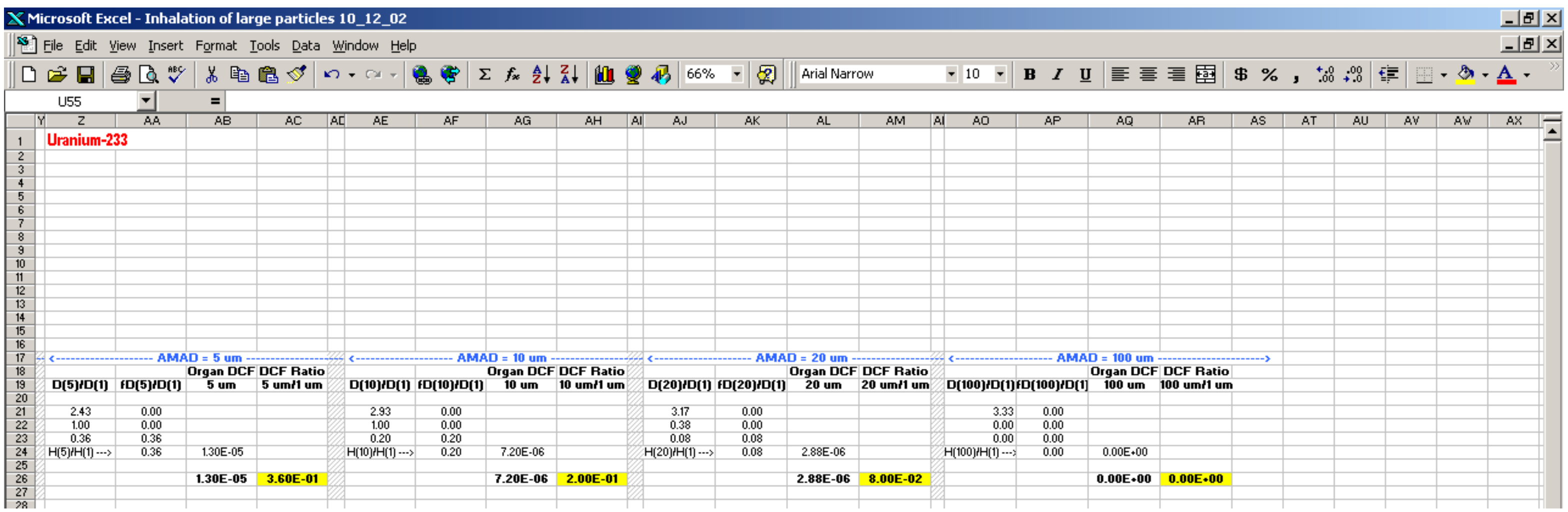
	AMAD = 0.2 um			
	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
N-P	0.17	0.00		
T-B	1.00	0.00		
P	2.00	2.00		
	H(0.2)/H(1) --->	2.00	7.20E-05	
Sum			**7.20E-05**	**2.00E+00**

	AMAD = 0.5 um			
	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
N-P	0.57	0.00		
T-B	1.00	0.00		
P	1.40	1.40		
	H(0.5)/H(1) --->	1.40	5.04E-05	
Sum			**5.04E-05**	**1.40E+00**

	AMAD = 2 um			
	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
N-P	1.60	0.00		
T-B	1.00	0.00		
P	0.68	0.68		
	H(2)/H(1) --->	0.68	2.45E-05	
Sum			**2.45E-05**	**6.80E-01**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-233

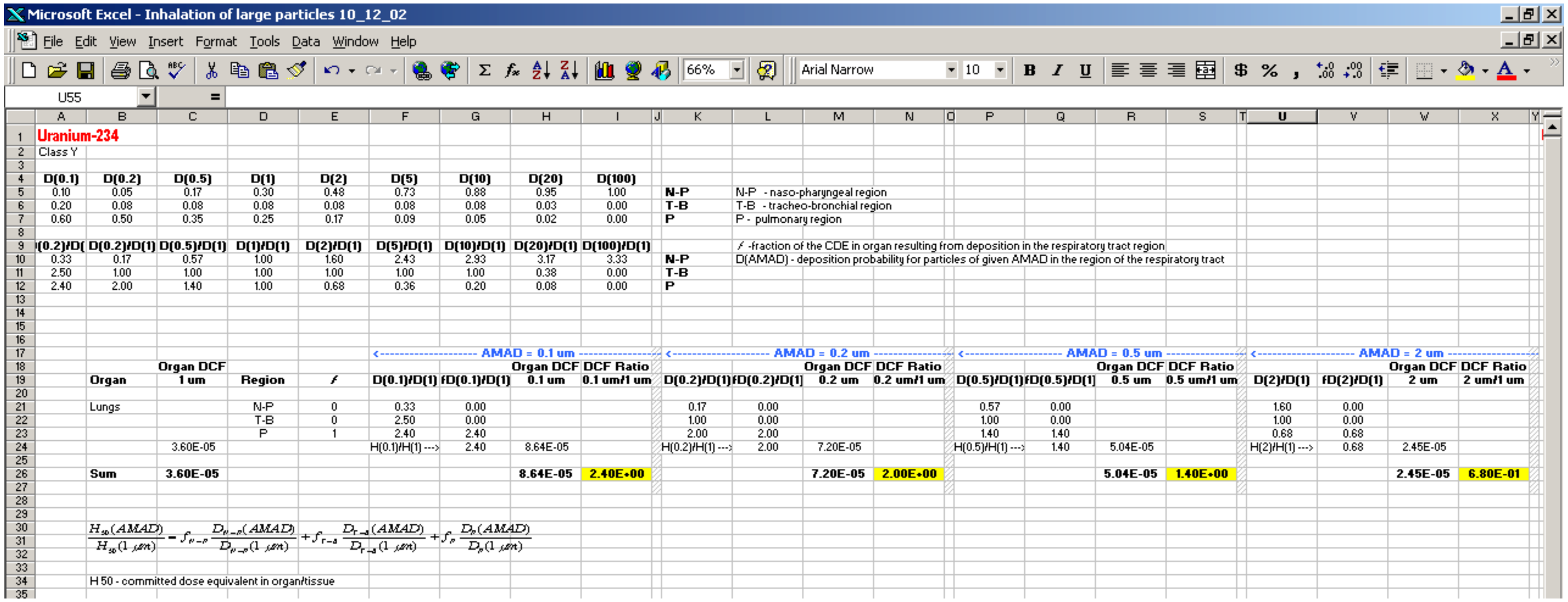
	AMAD = 5 um			
	D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
N-P	2.43	0.00		
T-B	1.00	0.00		
P	0.36	0.36		
	H(5)/H(1) --->	0.36	1.30E-05	
Sum			**1.30E-05**	**3.60E-01**

	AMAD = 10 um			
	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
N-P	2.93	0.00		
T-B	1.00	0.00		
P	0.20	0.20		
	H(10)/H(1) --->	0.20	7.20E-06	
Sum			**7.20E-06**	**2.00E-01**

	AMAD = 20 um			
	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
N-P	3.17	0.00		
T-B	0.38	0.00		
P	0.08	0.08		
	H(20)/H(1) --->	0.08	2.88E-06	
Sum			**2.88E-06**	**8.00E-02**

	AMAD = 100 um			
	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
N-P	3.33	0.00		
T-B	0.00	0.00		
P	0.00	0.00		
	H(100)/H(1) --->	0.00	0.00E+00	
Sum			**0.00E+00**	**0.00E+00**

Figure II-17. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Uranium-233



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-234

Class Y

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region

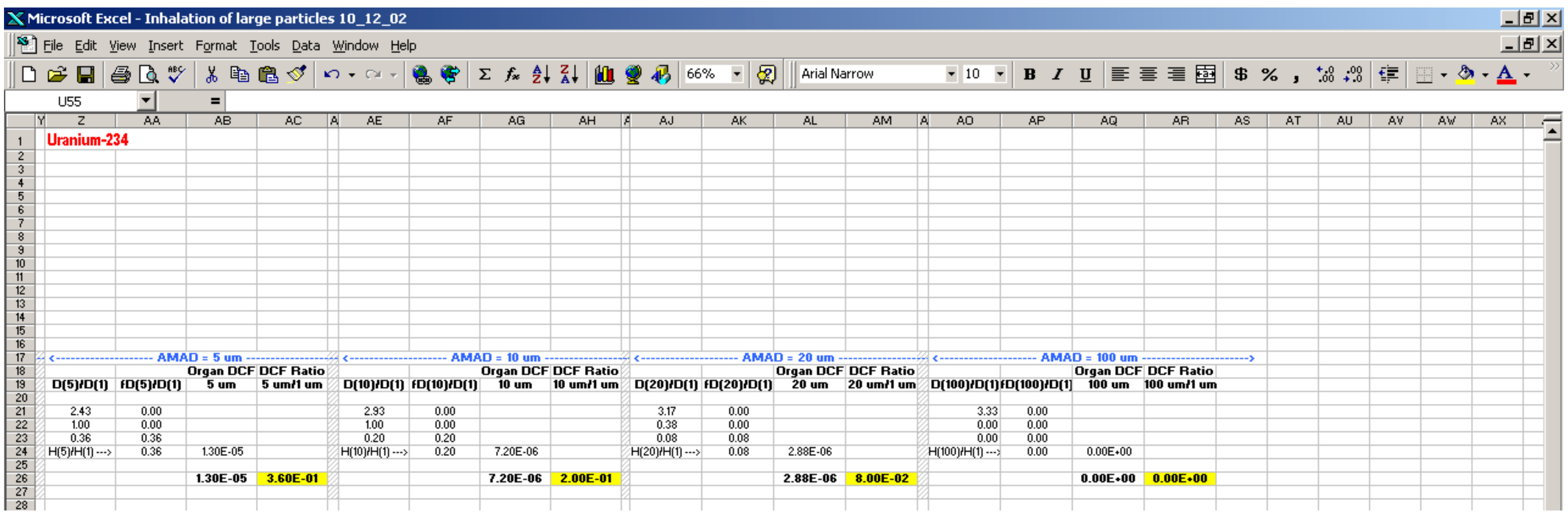
D(0.2)/D(	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)		
										f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

	Organ DCF			AMAD = 0.1 um			
Organ	**Organ DCF 1 um**	**Region**	***f***	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**Organ DCF 0.1 um**	**DCF Ratio 0.1 um/1 um**
Lungs		N-P	0	0.33	0.00		
		T-B	0	2.50	0.00		
		P	1	2.40	2.40		
	3.60E-05			H(0.1)/H(1) --->	2.40	8.64E-05	
Sum	**3.60E-05**					**8.64E-05**	**2.40E+00**

AMAD = 0.2 um				AMAD = 0.5 um				AMAD = 2 um			
D(0.2)/D(1)	**fD(0.2)/D(1)**	**Organ DCF 0.2 um**	**DCF Ratio 0.2 um/1 um**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**Organ DCF 0.5 um**	**DCF Ratio 0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**Organ DCF 2 um**	**DCF Ratio 2 um/1 um**
0.17	0.00			0.57	0.00			1.60	0.00		
1.00	0.00			1.00	0.00			1.00	0.00		
2.00	2.00			1.40	1.40			0.68	0.68		
H(0.2)/H(1) --->	2.00	7.20E-05		H(0.5)/H(1) --->	1.40	5.04E-05		H(2)/H(1) --->	0.68	2.45E-05	
		7.20E-05	**2.00E+00**			**5.04E-05**	**1.40E+00**			**2.45E-05**	**6.80E-01**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



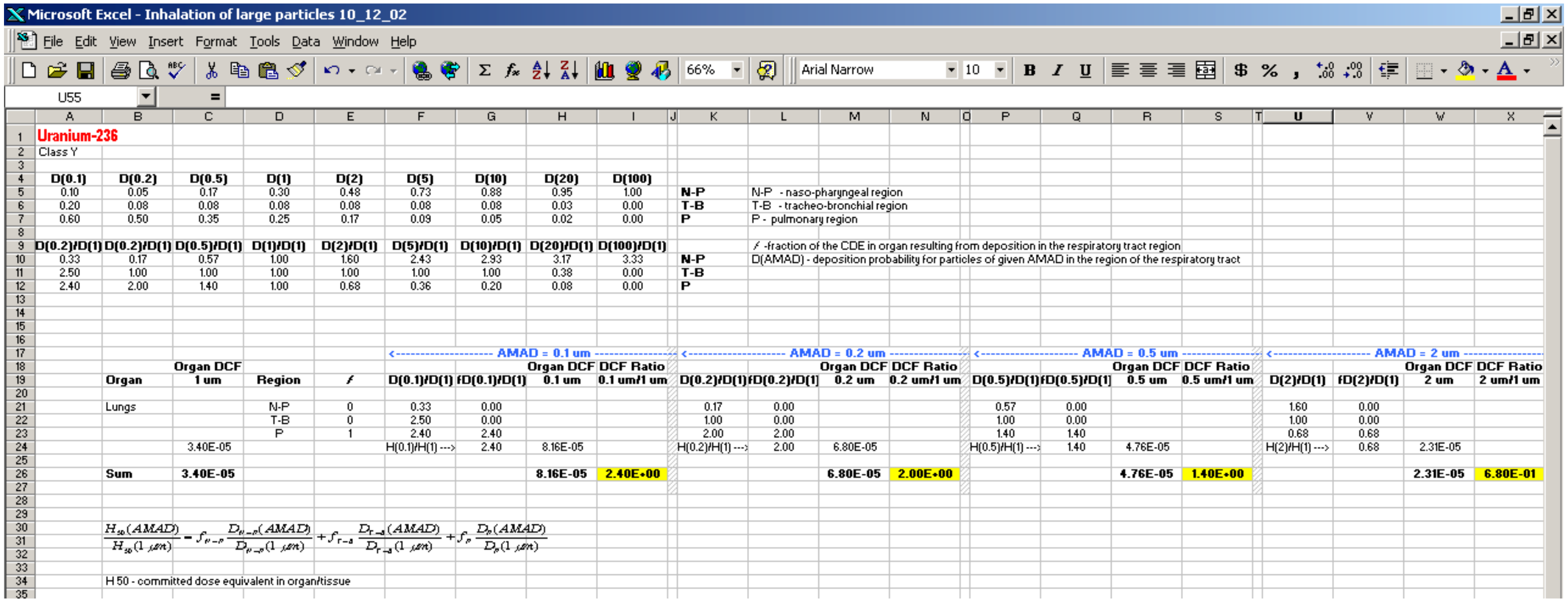
Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-234

AMAD = 5 um				AMAD = 10 um			
D(5)/D(1)	**fD(5)/D(1)**	**Organ DCF 5 um**	**DCF Ratio 5 um/1 um**	**D(10)/D(1)**	**fD(10)/D(1)**	**Organ DCF 10 um**	**DCF Ratio 10 um/1 um**
2.43	0.00			2.93	0.00		
1.00	0.00			1.00	0.00		
0.36	0.36			0.20	0.20		
H(5)/H(1) --->	0.36	1.30E-05		H(10)/H(1) --->	0.20	7.20E-06	
		1.30E-05	**3.60E-01**			**7.20E-06**	**2.00E-01**

AMAD = 20 um				AMAD = 100 um			
D(20)/D(1)	**fD(20)/D(1)**	**Organ DCF 20 um**	**DCF Ratio 20 um/1 um**	**D(100)/D(1)**	**fD(100)/D(1)**	**Organ DCF 100 um**	**DCF Ratio 100 um/1 um**
3.17	0.00			3.33	0.00		
0.38	0.00			0.00	0.00		
0.08	0.08			0.00	0.00		
H(20)/H(1) --->	0.08	2.88E-06		H(100)/H(1) --->	0.00	0.00E+00	
		2.88E-06	**8.00E-02**			**0.00E+00**	**0.00E+00**

Figure II-18. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Uranium-234



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-236

Class Y

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

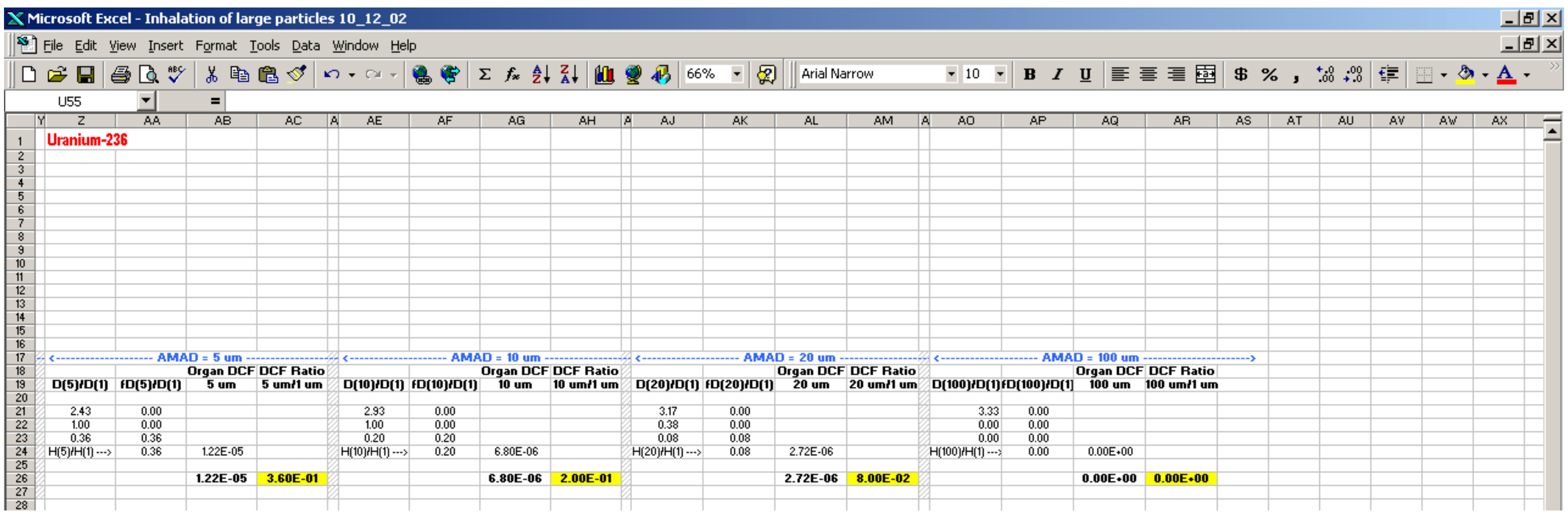
f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	f
Lungs		N-P	0
		T-B	0
		P	1
	3.40E-05		
Sum	**3.40E-05**		

<------ AMAD = 0.1 um ------				<------ AMAD = 0.2 um ------				<------ AMAD = 0.5 um ------				<------ AMAD = 2 um ------			
D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
0.33	0.00			0.17	0.00			0.57	0.00			1.60	0.00		
2.50	0.00			1.00	0.00			1.00	0.00			1.00	0.00		
2.40	2.40			2.00	2.00			1.40	1.40			0.68	0.68		
H(0.1)/H(1) --->	2.40	8.16E-05		H(0.2)/H(1) --->	2.00	6.80E-05		H(0.5)/H(1) --->	1.40	4.76E-05		H(2)/H(1) --->	0.68	2.31E-05	
		8.16E-05	**2.40E+00**			**6.80E-05**	**2.00E+00**			**4.76E-05**	**1.40E+00**			**2.31E-05**	**6.80E-01**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue



Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-236

<------ AMAD = 5 um ------				<------ AMAD = 10 um ------				<------ AMAD = 20 um ------				<------ AMAD = 100 um ------>			
D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
2.43	0.00			2.93	0.00			3.17	0.00			3.33	0.00		
1.00	0.00			1.00	0.00			0.38	0.00			0.00	0.00		
0.36	0.36			0.20	0.20			0.08	0.08			0.00	0.00		
H(5)/H(1) --->	0.36	1.22E-05		H(10)/H(1) --->	0.20	6.80E-06		H(20)/H(1) --->	0.08	2.72E-06		H(100)/H(1) --->	0.00	0.00E+00	
		1.22E-05	**3.60E-01**			**6.80E-06**	**2.00E-01**			**2.72E-06**	**8.00E-02**			**0.00E+00**	**0.00E+00**

Figure II-19. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 μm Particles for Uranium-236

Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-238

Class Y

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

f - fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

Organ	Organ DCF 1 um	Region	*f*
Lungs		N-P	0
		T-B	0
		P	1
	3.20E-05		
Sum	**3.20E-05**		

AMAD = 0.1 um

D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
0.33	0.00		
2.50	0.00		
2.40	2.40		
H(0.1)/H(1) --->	2.40	7.68E-05	
		7.68E-05	**2.40E+00**

AMAD = 0.2 um

D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
0.17	0.00		
1.00	0.00		
2.00	2.00		
H(0.2)/H(1) --->	2.00	6.40E-05	
		6.40E-05	**2.00E+00**

AMAD = 0.5 um

D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
0.57	0.00		
1.00	0.00		
1.40	1.40		
H(0.5)/H(1) --->	1.40	4.48E-05	
		4.48E-05	**1.40E+00**

AMAD = 2 um

D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
1.60	0.00		
1.00	0.00		
0.68	0.68		
H(2)/H(1) --->	0.68	2.18E-05	
		2.18E-05	**6.80E-01**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Microsoft Excel - Inhalation of large particles 10_12_02

Uranium-238

AMAD = 5 um

D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
2.43	0.00		
1.00	0.00		
0.36	0.36		
H(5)/H(1) --->	0.36	1.15E-05	
		1.15E-05	**3.60E-01**

AMAD = 10 um

D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
2.93	0.00		
1.00	0.00		
0.20	0.20		
H(10)/H(1) --->	0.20	6.40E-06	
		6.40E-06	**2.00E-01**

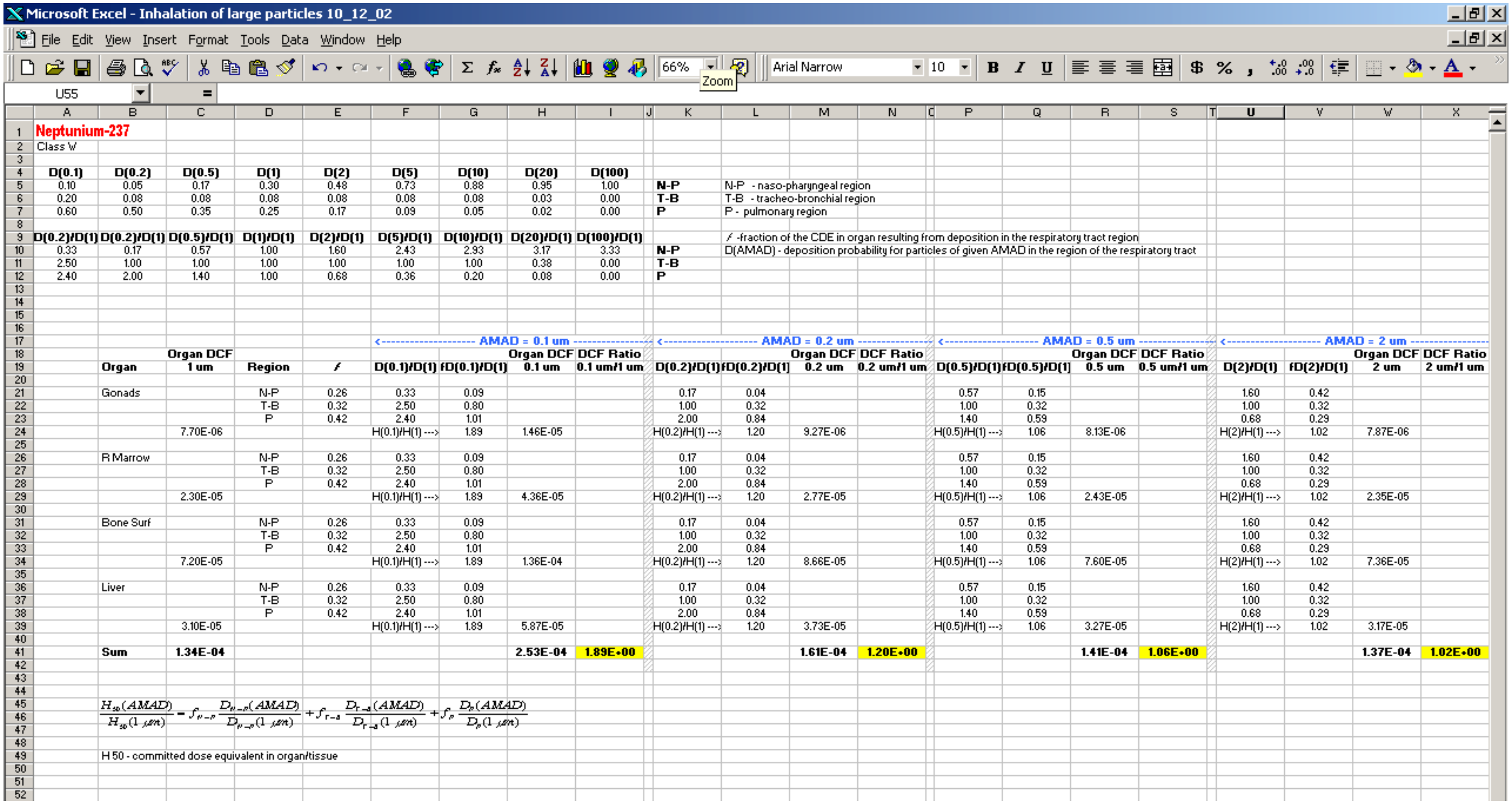
AMAD = 20 um

D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
3.17	0.00		
0.38	0.00		
0.08	0.08		
H(20)/H(1) --->	0.08	2.56E-06	
		2.56E-06	**8.00E-02**

AMAD = 100 um

D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
3.33	0.00		
0.00	0.00		
0.00	0.00		
H(100)/H(1) --->	0.00	0.00E+00	
		0.00E+00	**0.00E+00**

Figure II-20. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 100 µm Particles for Uranium-238



Neptunium-237

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
D(0.2)/D(1)	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		*f* -fraction of the CDE in organ resulting from deposition in the respiratory tract region
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

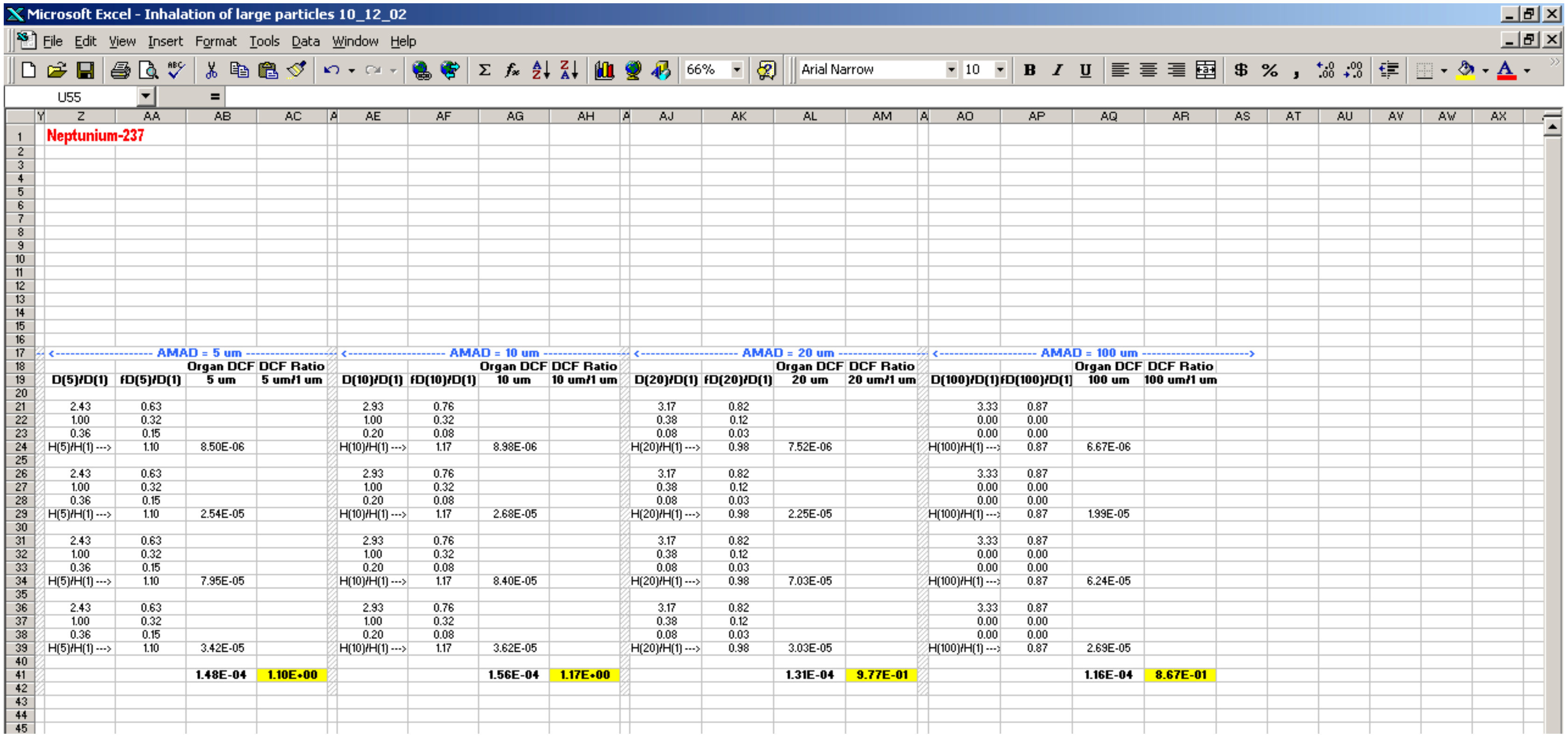
				AMAD = 0.1 um				AMAD = 0.2 um			
Organ	**Organ DCF 1 um**	**Region**	***f***	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**Organ DCF 0.1 um**	**DCF Ratio 0.1 um/1 um**	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**Organ DCF 0.2 um**	**DCF Ratio 0.2 um/1 um**
Gonads		N-P	0.26	0.33	0.09			0.17	0.04		
		T-B	0.32	2.50	0.80			1.00	0.32		
		P	0.42	2.40	1.01			2.00	0.84		
	7.70E-06			H(0.1)/H(1) --->	1.89	1.46E-05		H(0.2)/H(1) --->	1.20	9.27E-06	
R Marrow		N-P	0.26	0.33	0.09			0.17	0.04		
		T-B	0.32	2.50	0.80			1.00	0.32		
		P	0.42	2.40	1.01			2.00	0.84		
	2.30E-05			H(0.1)/H(1) --->	1.89	4.36E-05		H(0.2)/H(1) --->	1.20	2.77E-05	
Bone Surf		N-P	0.26	0.33	0.09			0.17	0.04		
		T-B	0.32	2.50	0.80			1.00	0.32		
		P	0.42	2.40	1.01			2.00	0.84		
	7.20E-05			H(0.1)/H(1) --->	1.89	1.36E-04		H(0.2)/H(1) --->	1.20	8.66E-05	
Liver		N-P	0.26	0.33	0.09			0.17	0.04		
		T-B	0.32	2.50	0.80			1.00	0.32		
		P	0.42	2.40	1.01			2.00	0.84		
	3.10E-05			H(0.1)/H(1) --->	1.89	5.87E-05		H(0.2)/H(1) --->	1.20	3.73E-05	
Sum	**1.34E-04**					**2.53E-04**	**1.89E+00**			**1.61E-04**	**1.20E+00**

		AMAD = 0.5 um				AMAD = 2 um			
Organ	**Region**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**Organ DCF 0.5 um**	**DCF Ratio 0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**Organ DCF 2 um**	**DCF Ratio 2 um/1 um**
Gonads	N-P	0.57	0.15			1.60	0.42		
	T-B	1.00	0.32			1.00	0.32		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	8.13E-06		H(2)/H(1) --->	1.02	7.87E-06	
R Marrow	N-P	0.57	0.15			1.60	0.42		
	T-B	1.00	0.32			1.00	0.32		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	2.43E-05		H(2)/H(1) --->	1.02	2.35E-05	
Bone Surf	N-P	0.57	0.15			1.60	0.42		
	T-B	1.00	0.32			1.00	0.32		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	7.60E-05		H(2)/H(1) --->	1.02	7.36E-05	
Liver	N-P	0.57	0.15			1.60	0.42		
	T-B	1.00	0.32			1.00	0.32		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	3.27E-05		H(2)/H(1) --->	1.02	3.17E-05	
Sum				**1.41E-04**	**1.06E+00**			**1.37E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\,\mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\,\mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\,\mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\,\mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-21a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Neptunium-237



Row	D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
17	<------------------ AMAD = 5 um			------------------	<------------------ AMAD = 10 um			------------------
21	2.43	0.63			2.93	0.76		
22	1.00	0.32			1.00	0.32		
23	0.36	0.15			0.20	0.08		
24	H(5)/H(1) --->	1.10	8.50E-06		H(10)/H(1) --->	1.17	8.98E-06	
26	2.43	0.63			2.93	0.76		
27	1.00	0.32			1.00	0.32		
28	0.36	0.15			0.20	0.08		
29	H(5)/H(1) --->	1.10	2.54E-05		H(10)/H(1) --->	1.17	2.68E-05	
31	2.43	0.63			2.93	0.76		
32	1.00	0.32			1.00	0.32		
33	0.36	0.15			0.20	0.08		
34	H(5)/H(1) --->	1.10	7.95E-05		H(10)/H(1) --->	1.17	8.40E-05	
36	2.43	0.63			2.93	0.76		
37	1.00	0.32			1.00	0.32		
38	0.36	0.15			0.20	0.08		
39	H(5)/H(1) --->	1.10	3.42E-05		H(10)/H(1) --->	1.17	3.62E-05	
41			**1.48E-04**	**1.10E+00**			**1.56E-04**	**1.17E+00**

Row	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
17	<------------------ AMAD = 20 um			------------------	<------------------ AMAD = 100 um			------------------>
21	3.17	0.82			3.33	0.87		
22	0.38	0.12			0.00	0.00		
23	0.08	0.03			0.00	0.00		
24	H(20)/H(1) --->	0.98	7.52E-06		H(100)/H(1) --->	0.87	6.67E-06	
26	3.17	0.82			3.33	0.87		
27	0.38	0.12			0.00	0.00		
28	0.08	0.03			0.00	0.00		
29	H(20)/H(1) --->	0.98	2.25E-05		H(100)/H(1) --->	0.87	1.99E-05	
31	3.17	0.82			3.33	0.87		
32	0.38	0.12			0.00	0.00		
33	0.08	0.03			0.00	0.00		
34	H(20)/H(1) --->	0.98	7.03E-05		H(100)/H(1) --->	0.87	6.24E-05	
36	3.17	0.82			3.33	0.87		
37	0.38	0.12			0.00	0.00		
38	0.08	0.03			0.00	0.00		
39	H(20)/H(1) --->	0.98	3.03E-05		H(100)/H(1) --->	0.87	2.69E-05	
41			**1.31E-04**	**9.77E-01**			**1.16E-04**	**8.67E-01**

Figure II-21b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Neptunium-237

Microsoft Excel - Inhalation of large particles 10_12_02

Plutonium-238

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

f - fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

AMAD = 0.1 um

Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Gonads		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.00E-06			H(0.1)/H(1) --->	1.92	1.34E-05	
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.10E-05			H(0.1)/H(1) --->	1.92	4.02E-05	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	6.60E-05			H(0.1)/H(1) --->	1.92	1.26E-04	
Liver		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.90E-05			H(0.1)/H(1) --->	1.92	5.56E-05	
Sum	**1.23E-04**					**2.36E-04**	**1.92E+00**

AMAD = 0.2 um

Organ	Region	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	8.48E-06	
R Marrow	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	2.54E-05	
Bone Surf	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	8.00E-05	
Liver	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	3.51E-05	
Sum				**1.49E-04**	**1.21E+00**

AMAD = 0.5 um

Organ	Region	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
Gonads	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	7.42E-06	
R Marrow	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	2.23E-05	
Bone Surf	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	6.99E-05	
Liver	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	3.07E-05	
Sum				**1.30E-04**	**1.06E+00**

AMAD = 2 um

Organ	Region	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	7.11E-06	
R Marrow	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	2.13E-05	
Bone Surf	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	6.70E-05	
Liver	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	2.95E-05	
Sum				**1.25E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-22a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Plutonium-238

Microsoft Excel - Inhalation of large particles 10_12_02

File Edit View Insert Format Tools Data Window Help

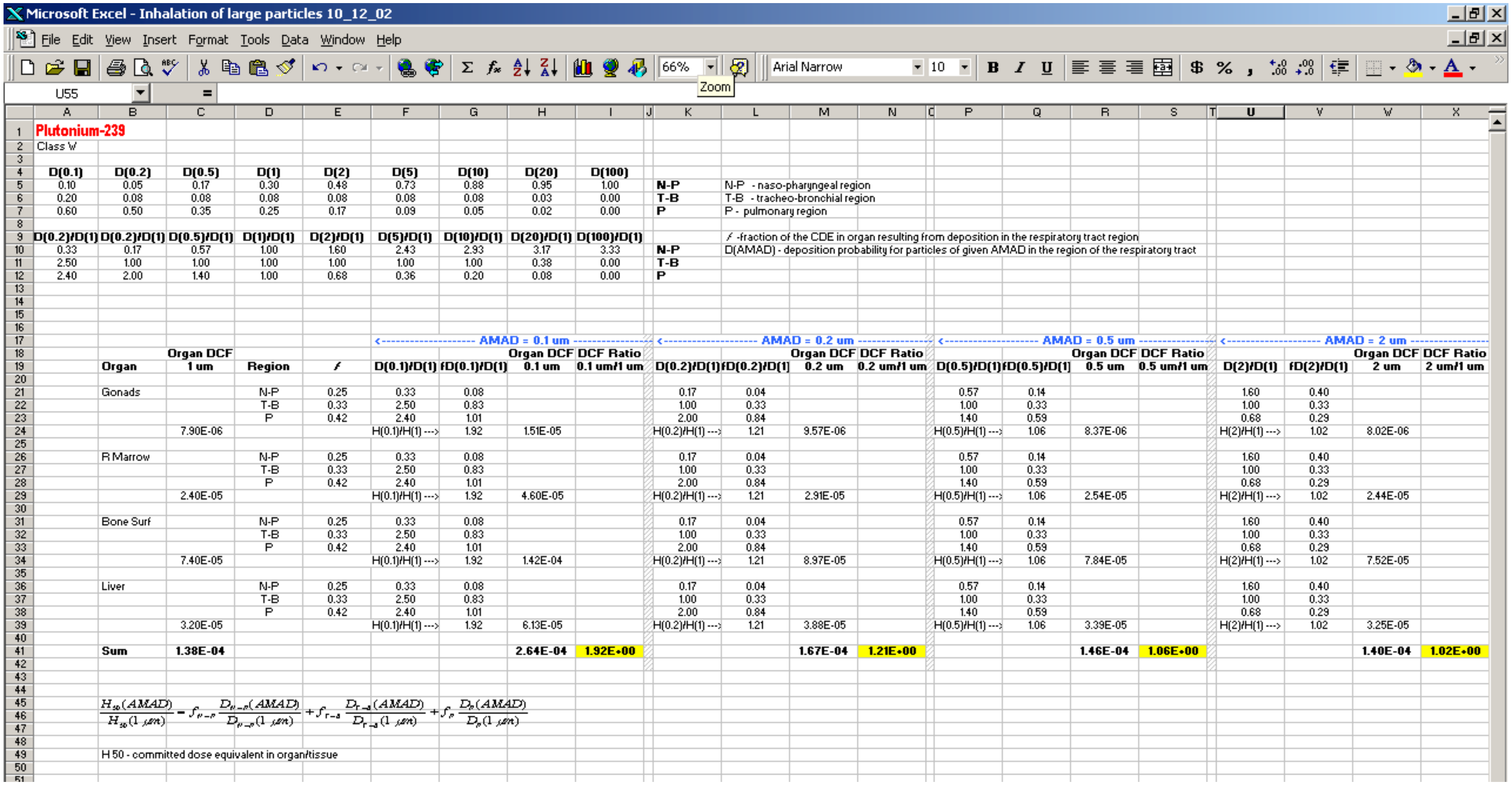
U55 =

Plutonium-238

Row	Z	AA	AB	AC	AE	AF	AG	AH
17	<------------------ AMAD = 5 um			------------------	<------------------ AMAD = 10 um			------------------
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um
21	2.43	0.61			2.93	0.73		
22	1.00	0.33			1.00	0.33		
23	0.36	0.15			0.20	0.08		
24	H(5)/H(1) --->	1.09	7.63E-06		H(10)/H(1) --->	1.15	8.03E-06	
26	2.43	0.61			2.93	0.73		
27	1.00	0.33			1.00	0.33		
28	0.36	0.15			0.20	0.08		
29	H(5)/H(1) --->	1.09	2.29E-05		H(10)/H(1) --->	1.15	2.41E-05	
31	2.43	0.61			2.93	0.73		
32	1.00	0.33			1.00	0.33		
33	0.36	0.15			0.20	0.08		
34	H(5)/H(1) --->	1.09	7.19E-05		H(10)/H(1) --->	1.15	7.57E-05	
36	2.43	0.61			2.93	0.73		
37	1.00	0.33			1.00	0.33		
38	0.36	0.15			0.20	0.08		
39	H(5)/H(1) --->	1.09	3.16E-05		H(10)/H(1) --->	1.15	3.33E-05	
41			**1.34E-04**	**1.09E+00**			**1.41E-04**	**1.15E+00**

Row	AJ	AK	AL	AM	AO	AP	AQ	AR
17	<------------------ AMAD = 20 um			------------------	<------------------ AMAD = 100 um			------------------>
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	3.17	0.79			3.33	0.83		
22	0.38	0.12			0.00	0.00		
23	0.08	0.03			0.00	0.00		
24	H(20)/H(1) --->	0.95	6.64E-06		H(100)/H(1) --->	0.83	5.83E-06	
26	3.17	0.79			3.33	0.83		
27	0.38	0.12			0.00	0.00		
28	0.08	0.03			0.00	0.00		
29	H(20)/H(1) --->	0.95	1.99E-05		H(100)/H(1) --->	0.83	1.75E-05	
31	3.17	0.79			3.33	0.83		
32	0.38	0.12			0.00	0.00		
33	0.08	0.03			0.00	0.00		
34	H(20)/H(1) --->	0.95	6.26E-05		H(100)/H(1) --->	0.83	5.50E-05	
36	3.17	0.79			3.33	0.83		
37	0.38	0.12			0.00	0.00		
38	0.08	0.03			0.00	0.00		
39	H(20)/H(1) --->	0.95	2.75E-05		H(100)/H(1) --->	0.83	2.42E-05	
41			**1.17E-04**	**9.49E-01**			**1.03E-04**	**8.33E-01**

Figure II-22b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Plutonium-238



Microsoft Excel - Inhalation of large particles 10_12_02

Plutonium-239

Class W

Region	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)
N-P	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00
T-B	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00
P	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00

Region	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)
N-P	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33
T-B	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00
P	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

AMAD = 0.1 um

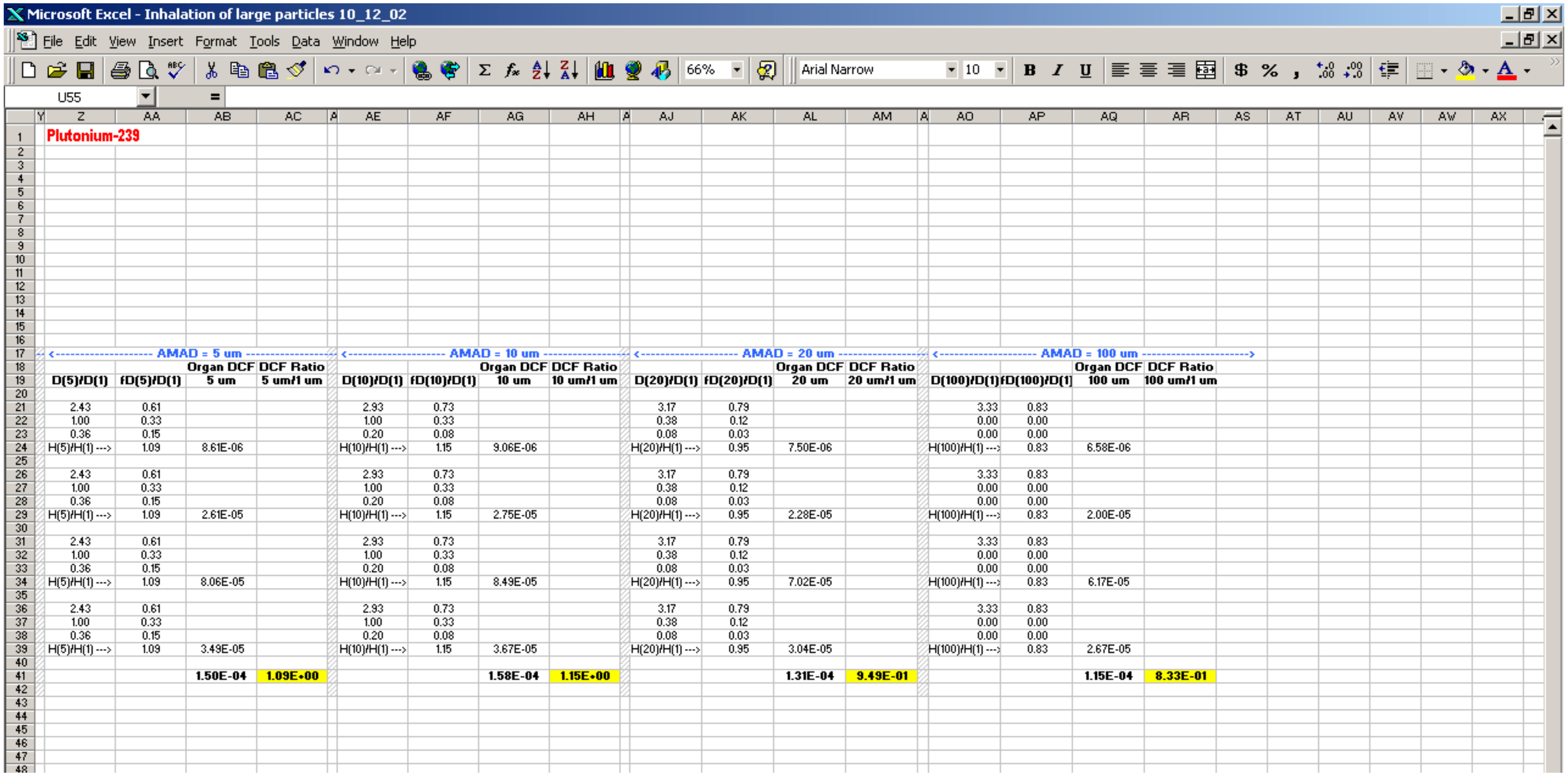
Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Gonads		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.90E-06			H(0.1)/H(1) --->	1.92	1.51E-05	
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.40E-05			H(0.1)/H(1) --->	1.92	4.60E-05	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.40E-05			H(0.1)/H(1) --->	1.92	1.42E-04	
Liver		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	3.20E-05			H(0.1)/H(1) --->	1.92	6.13E-05	
Sum	**1.38E-04**					**2.64E-04**	**1.92E+00**

Organ / Region	AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads N-P	0.17	0.04			0.57	0.14			1.60	0.40		
T-B	1.00	0.33			1.00	0.33			1.00	0.33		
P	2.00	0.84			1.40	0.59			0.68	0.29		
	H(0.2)/H(1) --->	1.21	9.57E-06		H(0.5)/H(1) --->	1.06	8.37E-06		H(2)/H(1) --->	1.02	8.02E-06	
R Marrow N-P	0.17	0.04			0.57	0.14			1.60	0.40		
T-B	1.00	0.33			1.00	0.33			1.00	0.33		
P	2.00	0.84			1.40	0.59			0.68	0.29		
	H(0.2)/H(1) --->	1.21	2.91E-05		H(0.5)/H(1) --->	1.06	2.54E-05		H(2)/H(1) --->	1.02	2.44E-05	
Bone Surf N-P	0.17	0.04			0.57	0.14			1.60	0.40		
T-B	1.00	0.33			1.00	0.33			1.00	0.33		
P	2.00	0.84			1.40	0.59			0.68	0.29		
	H(0.2)/H(1) --->	1.21	8.97E-05		H(0.5)/H(1) --->	1.06	7.84E-05		H(2)/H(1) --->	1.02	7.52E-05	
Liver N-P	0.17	0.04			0.57	0.14			1.60	0.40		
T-B	1.00	0.33			1.00	0.33			1.00	0.33		
P	2.00	0.84			1.40	0.59			0.68	0.29		
	H(0.2)/H(1) --->	1.21	3.88E-05		H(0.5)/H(1) --->	1.06	3.39E-05		H(2)/H(1) --->	1.02	3.25E-05	
Sum			**1.67E-04**	**1.21E+00**			**1.46E-04**	**1.06E+00**			**1.40E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-23a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Plutonium-239



Microsoft Excel - Inhalation of large particles 10_12_02

U55

1 Plutonium-239

Row	Z	AA	AB	AC
17	<------ AMAD = 5 um ------			
18			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um
21	2.43	0.61		
22	1.00	0.33		
23	0.36	0.15		
24	H(5)/H(1) --->	1.09	8.61E-06	
26	2.43	0.61		
27	1.00	0.33		
28	0.36	0.15		
29	H(5)/H(1) --->	1.09	2.61E-05	
31	2.43	0.61		
32	1.00	0.33		
33	0.36	0.15		
34	H(5)/H(1) --->	1.09	8.06E-05	
36	2.43	0.61		
37	1.00	0.33		
38	0.36	0.15		
39	H(5)/H(1) --->	1.09	3.49E-05	
41			1.50E-04	1.09E+00

Row	AE	AF	AG	AH
17	<------ AMAD = 10 um ------			
18			Organ DCF	DCF Ratio
19	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um
21	2.93	0.73		
22	1.00	0.33		
23	0.20	0.08		
24	H(10)/H(1) --->	1.15	9.06E-06	
26	2.93	0.73		
27	1.00	0.33		
28	0.20	0.08		
29	H(10)/H(1) --->	1.15	2.75E-05	
31	2.93	0.73		
32	1.00	0.33		
33	0.20	0.08		
34	H(10)/H(1) --->	1.15	8.49E-05	
36	2.93	0.73		
37	1.00	0.33		
38	0.20	0.08		
39	H(10)/H(1) --->	1.15	3.67E-05	
41			1.58E-04	1.15E+00

Row	AJ	AK	AL	AM
17	<------ AMAD = 20 um ------			
18			Organ DCF	DCF Ratio
19	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um
21	3.17	0.79		
22	0.38	0.12		
23	0.08	0.03		
24	H(20)/H(1) --->	0.95	7.50E-06	
26	3.17	0.79		
27	0.38	0.12		
28	0.08	0.03		
29	H(20)/H(1) --->	0.95	2.28E-05	
31	3.17	0.79		
32	0.38	0.12		
33	0.08	0.03		
34	H(20)/H(1) --->	0.95	7.02E-05	
36	3.17	0.79		
37	0.38	0.12		
38	0.08	0.03		
39	H(20)/H(1) --->	0.95	3.04E-05	
41			1.31E-04	9.49E-01

Row	AO	AP	AQ	AR
17	<------ AMAD = 100 um ------>			
18			Organ DCF	DCF Ratio
19	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	3.33	0.83		
22	0.00	0.00		
23	0.00	0.00		
24	H(100)/H(1) --->	0.83	6.58E-06	
26	3.33	0.83		
27	0.00	0.00		
28	0.00	0.00		
29	H(100)/H(1) --->	0.83	2.00E-05	
31	3.33	0.83		
32	0.00	0.00		
33	0.00	0.00		
34	H(100)/H(1) --->	0.83	6.17E-05	
36	3.33	0.83		
37	0.00	0.00		
38	0.00	0.00		
39	H(100)/H(1) --->	0.83	2.67E-05	
41			1.15E-04	8.33E-01

Figure II-23b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Plutonium-239

Microsoft Excel - Inhalation of large particles 10_12_02

Plutonium-240

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

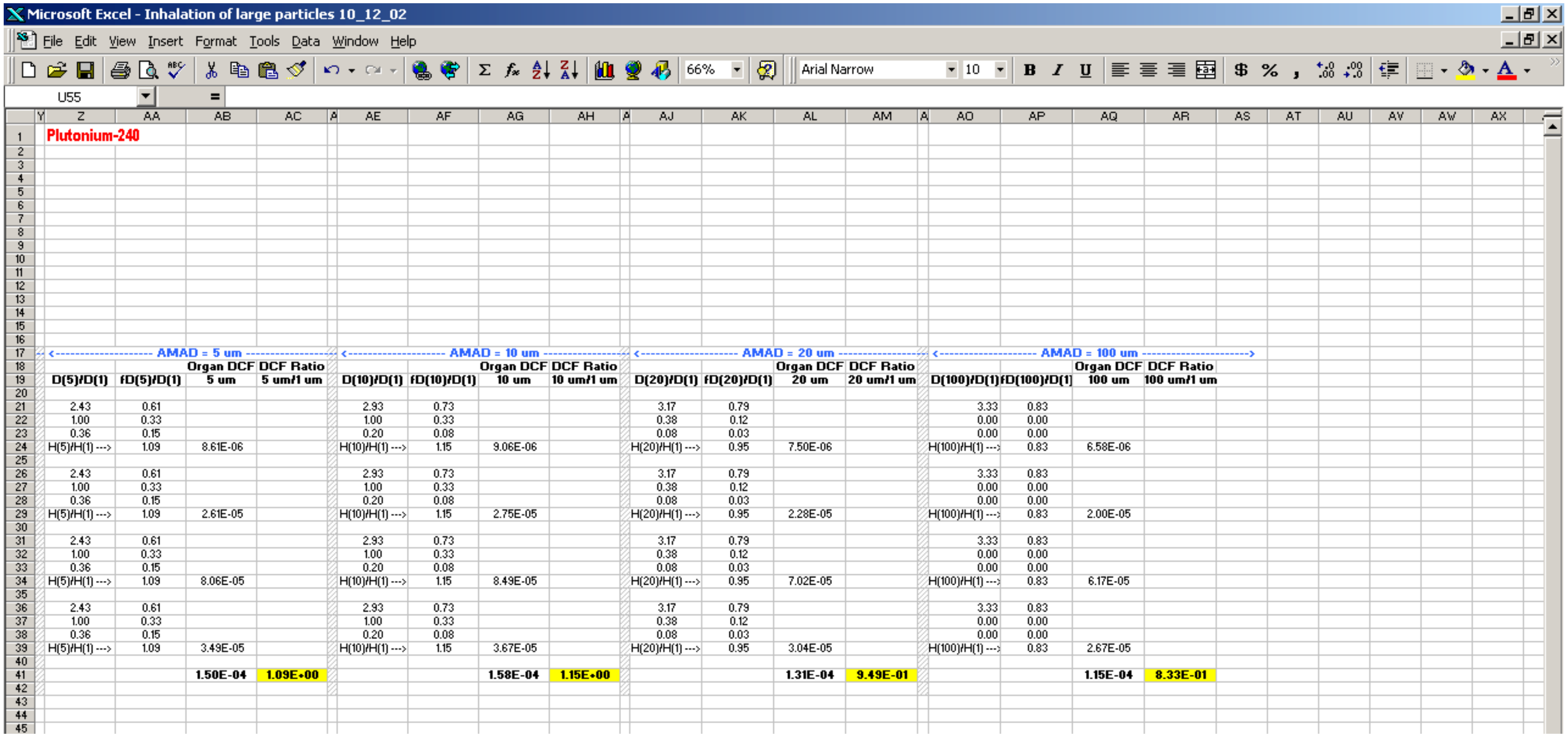
				<------ AMAD = 0.1 um ------				<------ AMAD = 0.2 um ------			
Organ	Organ DCF 1 um	Region	*f*	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	7.90E-06			H(0.1)/H(1) --->	1.92	1.51E-05		H(0.2)/H(1) --->	1.21	9.57E-06	
R Marrow		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	2.40E-05			H(0.1)/H(1) --->	1.92	4.60E-05		H(0.2)/H(1) --->	1.21	2.91E-05	
Bone Surf		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	7.40E-05			H(0.1)/H(1) --->	1.92	1.42E-04		H(0.2)/H(1) --->	1.21	8.97E-05	
Liver		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	3.20E-05			H(0.1)/H(1) --->	1.92	6.13E-05		H(0.2)/H(1) --->	1.21	3.88E-05	
Sum	**1.38E-04**					**2.64E-04**	**1.92E+00**			**1.67E-04**	**1.21E+00**

		<------ AMAD = 0.5 um ------				<------ AMAD = 2 um ------			
Organ	Region	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	N-P	0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	8.37E-06		H(2)/H(1) --->	1.02	8.02E-06	
R Marrow	N-P	0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	2.54E-05		H(2)/H(1) --->	1.02	2.44E-05	
Bone Surf	N-P	0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	7.84E-05		H(2)/H(1) --->	1.02	7.52E-05	
Liver	N-P	0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33		
	P	1.40	0.59			0.68	0.29		
		H(0.5)/H(1) --->	1.06	3.39E-05		H(2)/H(1) --->	1.02	3.25E-05	
Sum				**1.46E-04**	**1.06E+00**			**1.40E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-24a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Plutonium-240



Microsoft Excel - Inhalation of large particles 10_12_02

Plutonium-240

Row	Z	AA	AB	AC	AE	AF	AG	AH	AJ	AK	AL	AM	AO	AP	AQ	AR
17	<------------------- AMAD = 5 um			------------------	<------------------- AMAD = 10 um			------------------	<------------------- AMAD = 20 um			------------------	<------------------- AMAD = 100 um			------------------->
18			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19	D(5)/D(1)	fD(5)/D(1)	5 um	5 um/1 um	D(10)/D(1)	fD(10)/D(1)	10 um	10 um/1 um	D(20)/D(1)	fD(20)/D(1)	20 um	20 um/1 um	D(100)/D(1)	fD(100)/D(1)	100 um	100 um/1 um
21	2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
22	1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
23	0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
24	H(5)/H(1) --->	1.09	8.61E-06		H(10)/H(1) --->	1.15	9.06E-06		H(20)/H(1) --->	0.95	7.50E-06		H(100)/H(1) --->	0.83	6.58E-06	
26	2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
27	1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
28	0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
29	H(5)/H(1) --->	1.09	2.61E-05		H(10)/H(1) --->	1.15	2.75E-05		H(20)/H(1) --->	0.95	2.28E-05		H(100)/H(1) --->	0.83	2.00E-05	
31	2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
32	1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
33	0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
34	H(5)/H(1) --->	1.09	8.06E-05		H(10)/H(1) --->	1.15	8.49E-05		H(20)/H(1) --->	0.95	7.02E-05		H(100)/H(1) --->	0.83	6.17E-05	
36	2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
37	1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
38	0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
39	H(5)/H(1) --->	1.09	3.49E-05		H(10)/H(1) --->	1.15	3.67E-05		H(20)/H(1) --->	0.95	3.04E-05		H(100)/H(1) --->	0.83	2.67E-05	
41			**1.50E-04**	**1.09E+00**			**1.58E-04**	**1.15E+00**			**1.31E-04**	**9.49E-01**			**1.15E-04**	**8.33E-01**

Figure II-24b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Plutonium-240

Microsoft Excel - Inhalation of large particles 10_12_02

File Edit View Insert Format Tools Data Window Help

U55 =

Plutonium-242

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region

D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region

D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

AMAD = 0.1 um

Organ	Organ DCF 1 um	Region	f	D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um
Gonads		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.50E-06			H(0.1)/H(1) --->	1.92	1.44E-05	
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.30E-05			H(0.1)/H(1) --->	1.92	4.41E-05	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.00E-05			H(0.1)/H(1) --->	1.92	1.34E-04	
Liver		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	3.00E-05			H(0.1)/H(1) --->	1.92	5.75E-05	
Sum	**1.31E-04**					**2.50E-04**	**1.92E+00**

AMAD = 0.2 um

Organ	Region	D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	9.09E-06	
R Marrow	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	2.79E-05	
Bone Surf	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	8.48E-05	
Liver	N-P	0.17	0.04		
	T-B	1.00	0.33		
	P	2.00	0.84		
		H(0.2)/H(1) --->	1.21	3.64E-05	
Sum				**1.58E-04**	**1.21E+00**

AMAD = 0.5 um

Organ	Region	D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um
Gonads	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	7.95E-06	
R Marrow	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	2.44E-05	
Bone Surf	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	7.42E-05	
Liver	N-P	0.57	0.14		
	T-B	1.00	0.33		
	P	1.40	0.59		
		H(0.5)/H(1) --->	1.06	3.18E-05	
Sum				**1.38E-04**	**1.06E+00**

AMAD = 2 um

Organ	Region	D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	7.62E-06	
R Marrow	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	2.34E-05	
Bone Surf	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	7.11E-05	
Liver	N-P	1.60	0.40		
	T-B	1.00	0.33		
	P	0.68	0.29		
		H(2)/H(1) --->	1.02	3.05E-05	
Sum				**1.33E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-25a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Plutonium-242

Microsoft Excel - Inhalation of large particles 10_12_02

Plutonium-242

AMAD = 5 um				AMAD = 10 um				AMAD = 20 um				AMAD = 100 um			
D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	8.17E-06		H(10)/H(1) --->	1.15	8.61E-06		H(20)/H(1) --->	0.95	7.12E-06		H(100)/H(1) --->	0.83	6.25E-06	
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	2.51E-05		H(10)/H(1) --->	1.15	2.64E-05		H(20)/H(1) --->	0.95	2.18E-05		H(100)/H(1) --->	0.83	1.92E-05	
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	7.63E-05		H(10)/H(1) --->	1.15	8.03E-05		H(20)/H(1) --->	0.95	6.64E-05		H(100)/H(1) --->	0.83	5.83E-05	
2.43	0.61			2.93	0.73			3.17	0.79			3.33	0.83		
1.00	0.33			1.00	0.33			0.38	0.12			0.00	0.00		
0.36	0.15			0.20	0.08			0.08	0.03			0.00	0.00		
H(5)/H(1) --->	1.09	3.27E-05		H(10)/H(1) --->	1.15	3.44E-05		H(20)/H(1) --->	0.95	2.85E-05		H(100)/H(1) --->	0.83	2.50E-05	
		1.42E-04	**1.09E+00**			**1.50E-04**	**1.15E+00**			**1.24E-04**	**9.49E-01**			**1.09E-04**	**8.33E-01**

Figure II-25b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Plutonium-242

Microsoft Excel - Inhalation of large particles 10_12_02

Americium-241

Class W

D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)	
0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**
0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**
0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**
D(0.2)/D(1)	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**	
0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**
2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**
2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**

N-P - naso-pharyngeal region
T-B - tracheo-bronchial region
P - pulmonary region

f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract

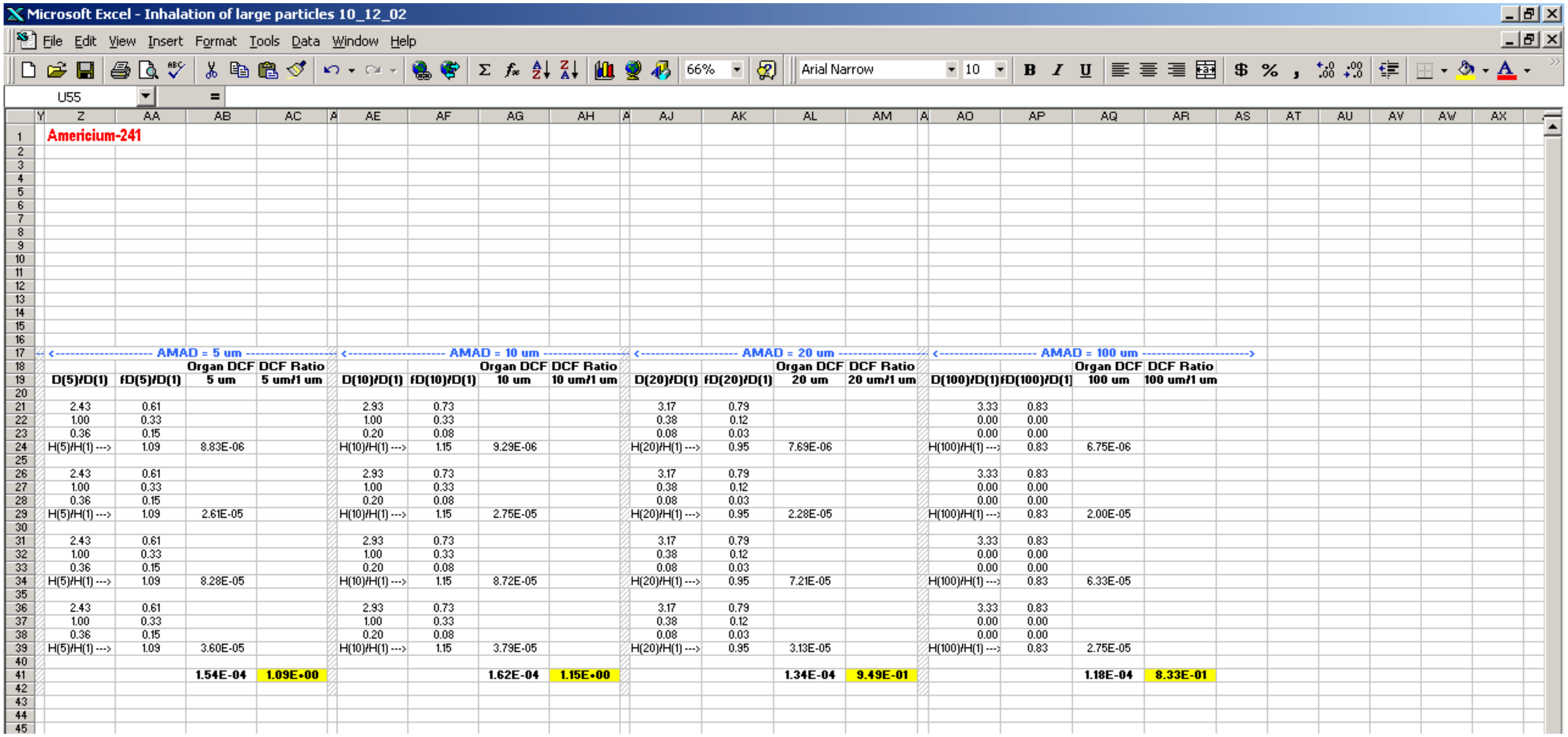
				AMAD = 0.1 um			
Organ	**Organ DCF 1 um**	**Region**	***f***	**D(0.1)/D(1)**	**fD(0.1)/D(1)**	**Organ DCF 0.1 um**	**DCF Ratio 0.1 um/1 um**
Gonads		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	8.10E-06			H(0.1)/H(1) --->	1.92	1.55E-05	
R Marrow		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	2.40E-05			H(0.1)/H(1) --->	1.92	4.60E-05	
Bone Surf		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	7.60E-05			H(0.1)/H(1) --->	1.92	1.46E-04	
Liver		N-P	0.25	0.33	0.08		
		T-B	0.33	2.50	0.83		
		P	0.42	2.40	1.01		
	3.30E-05			H(0.1)/H(1) --->	1.92	6.32E-05	
Sum	**1.41E-04**					**2.70E-04**	**1.92E+00**

		AMAD = 0.2 um				AMAD = 0.5 um				AMAD = 2 um			
Organ	**Region**	**D(0.2)/D(1)**	**fD(0.2)/D(1)**	**Organ DCF 0.2 um**	**DCF Ratio 0.2 um/1 um**	**D(0.5)/D(1)**	**fD(0.5)/D(1)**	**Organ DCF 0.5 um**	**DCF Ratio 0.5 um/1 um**	**D(2)/D(1)**	**fD(2)/D(1)**	**Organ DCF 2 um**	**DCF Ratio 2 um/1 um**
Gonads	N-P	0.17	0.04			0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33			1.00	0.33		
	P	2.00	0.84			1.40	0.59			0.68	0.29		
		H(0.2)/H(1) --->	1.21	9.81E-06		H(0.5)/H(1) --->	1.06	8.58E-06		H(2)/H(1) --->	1.02	8.23E-06	
R Marrow	N-P	0.17	0.04			0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33			1.00	0.33		
	P	2.00	0.84			1.40	0.59			0.68	0.29		
		H(0.2)/H(1) --->	1.21	2.91E-05		H(0.5)/H(1) --->	1.06	2.54E-05		H(2)/H(1) --->	1.02	2.44E-05	
Bone Surf	N-P	0.17	0.04			0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33			1.00	0.33		
	P	2.00	0.84			1.40	0.59			0.68	0.29		
		H(0.2)/H(1) --->	1.21	9.21E-05		H(0.5)/H(1) --->	1.06	8.05E-05		H(2)/H(1) --->	1.02	7.72E-05	
Liver	N-P	0.17	0.04			0.57	0.14			1.60	0.40		
	T-B	1.00	0.33			1.00	0.33			1.00	0.33		
	P	2.00	0.84			1.40	0.59			0.68	0.29		
		H(0.2)/H(1) --->	1.21	4.00E-05		H(0.5)/H(1) --->	1.06	3.50E-05		H(2)/H(1) --->	1.02	3.35E-05	
Sum				**1.71E-04**	**1.21E+00**			**1.50E-04**	**1.06E+00**			**1.43E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\,\mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\,\mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\,\mu m)} + f_{P}\frac{D_{P}(AMAD)}{D_{P}(1\,\mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-26a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Americium-241



Americium-241

AMAD = 5 um

Row	D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
21	2.43	0.61		
22	1.00	0.33		
23	0.36	0.15		
24	H(5)/H(1) --->	1.09	8.83E-06	
26	2.43	0.61		
27	1.00	0.33		
28	0.36	0.15		
29	H(5)/H(1) --->	1.09	2.61E-05	
31	2.43	0.61		
32	1.00	0.33		
33	0.36	0.15		
34	H(5)/H(1) --->	1.09	8.28E-05	
36	2.43	0.61		
37	1.00	0.33		
38	0.36	0.15		
39	H(5)/H(1) --->	1.09	3.60E-05	
41			**1.54E-04**	**1.09E+00**

AMAD = 10 um

Row	D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
21	2.93	0.73		
22	1.00	0.33		
23	0.20	0.08		
24	H(10)/H(1) --->	1.15	9.29E-06	
26	2.93	0.73		
27	1.00	0.33		
28	0.20	0.08		
29	H(10)/H(1) --->	1.15	2.75E-05	
31	2.93	0.73		
32	1.00	0.33		
33	0.20	0.08		
34	H(10)/H(1) --->	1.15	8.72E-05	
36	2.93	0.73		
37	1.00	0.33		
38	0.20	0.08		
39	H(10)/H(1) --->	1.15	3.79E-05	
41			**1.62E-04**	**1.15E+00**

AMAD = 20 um

Row	D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
21	3.17	0.79		
22	0.38	0.12		
23	0.08	0.03		
24	H(20)/H(1) --->	0.95	7.69E-06	
26	3.17	0.79		
27	0.38	0.12		
28	0.08	0.03		
29	H(20)/H(1) --->	0.95	2.28E-05	
31	3.17	0.79		
32	0.38	0.12		
33	0.08	0.03		
34	H(20)/H(1) --->	0.95	7.21E-05	
36	3.17	0.79		
37	0.38	0.12		
38	0.08	0.03		
39	H(20)/H(1) --->	0.95	3.13E-05	
41			**1.34E-04**	**9.49E-01**

AMAD = 100 um

Row	D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
21	3.33	0.83		
22	0.00	0.00		
23	0.00	0.00		
24	H(100)/H(1) --->	0.83	6.75E-06	
26	3.33	0.83		
27	0.00	0.00		
28	0.00	0.00		
29	H(100)/H(1) --->	0.83	2.00E-05	
31	3.33	0.83		
32	0.00	0.00		
33	0.00	0.00		
34	H(100)/H(1) --->	0.83	6.33E-05	
36	3.33	0.83		
37	0.00	0.00		
38	0.00	0.00		
39	H(100)/H(1) --->	0.83	2.75E-05	
41			**1.18E-04**	**8.33E-01**

Figure II-26b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Americium-241

Microsoft Excel - Inhalation of large particles 10_12_02

Americium-243

Class W

	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)		
	0.10	0.05	0.17	0.30	0.48	0.73	0.88	0.95	1.00	**N-P**	N-P - naso-pharyngeal region
	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0.00	**T-B**	T-B - tracheo-bronchial region
	0.60	0.50	0.35	0.25	0.17	0.09	0.05	0.02	0.00	**P**	P - pulmonary region
	D(0.2)/D(1)	**D(0.2)/D(1)**	**D(0.5)/D(1)**	**D(1)/D(1)**	**D(2)/D(1)**	**D(5)/D(1)**	**D(10)/D(1)**	**D(20)/D(1)**	**D(100)/D(1)**		f -fraction of the CDE in organ resulting from deposition in the respiratory tract region
	0.33	0.17	0.57	1.00	1.60	2.43	2.93	3.17	3.33	**N-P**	D(AMAD) - deposition probability for particles of given AMAD in the region of the respiratory tract
	2.50	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.00	**T-B**	
	2.40	2.00	1.40	1.00	0.68	0.36	0.20	0.08	0.00	**P**	

Organ	Organ DCF 1 um	Region	f	AMAD = 0.1 um: D(0.1)/D(1)	fD(0.1)/D(1)	Organ DCF 0.1 um	DCF Ratio 0.1 um/1 um	AMAD = 0.2 um: D(0.2)/D(1)	fD(0.2)/D(1)	Organ DCF 0.2 um	DCF Ratio 0.2 um/1 um
Gonads		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	8.10E-06			H(0.1)/H(1) --->	1.92	1.55E-05		H(0.2)/H(1) --->	1.21	9.81E-06	
R Marrow		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	2.40E-05			H(0.1)/H(1) --->	1.92	4.60E-05		H(0.2)/H(1) --->	1.21	2.91E-05	
Bone Surf		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	7.60E-05			H(0.1)/H(1) --->	1.92	1.46E-04		H(0.2)/H(1) --->	1.21	9.21E-05	
Liver		N-P	0.25	0.33	0.08			0.17	0.04		
		T-B	0.33	2.50	0.83			1.00	0.33		
		P	0.42	2.40	1.01			2.00	0.84		
	3.30E-05			H(0.1)/H(1) --->	1.92	6.32E-05		H(0.2)/H(1) --->	1.21	4.00E-05	
Sum	**1.41E-04**					**2.70E-04**	**1.92E+00**			**1.71E-04**	**1.21E+00**

Organ	AMAD = 0.5 um: D(0.5)/D(1)	fD(0.5)/D(1)	Organ DCF 0.5 um	DCF Ratio 0.5 um/1 um	AMAD = 2 um: D(2)/D(1)	fD(2)/D(1)	Organ DCF 2 um	DCF Ratio 2 um/1 um
Gonads	0.57	0.14			1.60	0.40		
	1.00	0.33			1.00	0.33		
	1.40	0.59			0.68	0.29		
	H(0.5)/H(1) --->	1.06	8.58E-06		H(2)/H(1) --->	1.02	8.23E-06	
R Marrow	0.57	0.14			1.60	0.40		
	1.00	0.33			1.00	0.33		
	1.40	0.59			0.68	0.29		
	H(0.5)/H(1) --->	1.06	2.54E-05		H(2)/H(1) --->	1.02	2.44E-05	
Bone Surf	0.57	0.14			1.60	0.40		
	1.00	0.33			1.00	0.33		
	1.40	0.59			0.68	0.29		
	H(0.5)/H(1) --->	1.06	8.05E-05		H(2)/H(1) --->	1.02	7.72E-05	
Liver	0.57	0.14			1.60	0.40		
	1.00	0.33			1.00	0.33		
	1.40	0.59			0.68	0.29		
	H(0.5)/H(1) --->	1.06	3.50E-05		H(2)/H(1) --->	1.02	3.35E-05	
Sum			**1.50E-04**	**1.06E+00**			**1.43E-04**	**1.02E+00**

$$\frac{H_{50}(AMAD)}{H_{50}(1\ \mu m)} = f_{N-P}\frac{D_{N-P}(AMAD)}{D_{N-P}(1\ \mu m)} + f_{T-B}\frac{D_{T-B}(AMAD)}{D_{T-B}(1\ \mu m)} + f_P\frac{D_P(AMAD)}{D_P(1\ \mu m)}$$

H 50 - committed dose equivalent in organ/tissue

Figure II-27a. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 0.1 to 2 μm Particles for Americium-243

Microsoft Excel - Inhalation of large particles 10_12_02

Americium-243

Row	AMAD = 5 um: D(5)/D(1)	fD(5)/D(1)	Organ DCF 5 um	DCF Ratio 5 um/1 um
21	2.43	0.61		
22	1.00	0.33		
23	0.36	0.15		
24	H(5)/H(1) --->	1.09	8.83E-06	
26	2.43	0.61		
27	1.00	0.33		
28	0.36	0.15		
29	H(5)/H(1) --->	1.09	2.61E-05	
31	2.43	0.61		
32	1.00	0.33		
33	0.36	0.15		
34	H(5)/H(1) --->	1.09	8.28E-05	
36	2.43	0.61		
37	1.00	0.33		
38	0.36	0.15		
39	H(5)/H(1) --->	1.09	3.60E-05	
41			**1.54E-04**	**1.09E+00**

Row	AMAD = 10 um: D(10)/D(1)	fD(10)/D(1)	Organ DCF 10 um	DCF Ratio 10 um/1 um
21	2.93	0.73		
22	1.00	0.33		
23	0.20	0.08		
24	H(10)/H(1) --->	1.15	9.29E-06	
26	2.93	0.73		
27	1.00	0.33		
28	0.20	0.08		
29	H(10)/H(1) --->	1.15	2.75E-05	
31	2.93	0.73		
32	1.00	0.33		
33	0.20	0.08		
34	H(10)/H(1) --->	1.15	8.72E-05	
36	2.93	0.73		
37	1.00	0.33		
38	0.20	0.08		
39	H(10)/H(1) --->	1.15	3.79E-05	
41			**1.62E-04**	**1.15E+00**

Row	AMAD = 20 um: D(20)/D(1)	fD(20)/D(1)	Organ DCF 20 um	DCF Ratio 20 um/1 um
21	3.17	0.79		
22	0.38	0.12		
23	0.08	0.03		
24	H(20)/H(1) --->	0.95	7.69E-06	
26	3.17	0.79		
27	0.38	0.12		
28	0.08	0.03		
29	H(20)/H(1) --->	0.95	2.28E-05	
31	3.17	0.79		
32	0.38	0.12		
33	0.08	0.03		
34	H(20)/H(1) --->	0.95	7.21E-05	
36	3.17	0.79		
37	0.38	0.12		
38	0.08	0.03		
39	H(20)/H(1) --->	0.95	3.13E-05	
41			**1.34E-04**	**9.49E-01**

Row	AMAD = 100 um: D(100)/D(1)	fD(100)/D(1)	Organ DCF 100 um	DCF Ratio 100 um/1 um
21	3.33	0.83		
22	0.00	0.00		
23	0.00	0.00		
24	H(100)/H(1) --->	0.83	6.75E-06	
26	3.33	0.83		
27	0.00	0.00		
28	0.00	0.00		
29	H(100)/H(1) --->	0.83	2.00E-05	
31	3.33	0.83		
32	0.00	0.00		
33	0.00	0.00		
34	H(100)/H(1) --->	0.83	6.33E-05	
36	3.33	0.83		
37	0.00	0.00		
38	0.00	0.00		
39	H(100)/H(1) --->	0.83	2.75E-05	
41			**1.18E-04**	**8.33E-01**

Figure II-27b. Image of Excel Spreadsheet Showing Calculation of Inhalation DCF Ratios for 5 to 100 μm Particles for Americium-243

Microsoft Excel - Inhalation of large particles 10_12_02

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L13 =

	A	B	C	D	E	F	G	H	I	K	L	M	N
1	Neptunium-237												
2	Class W												
3													
4	D(0.1)	D(0.2)	D(0.5)	D(1)	D(2)	D(5)	D(10)	D(20)	D(100)				
5	0.1	0.05	0.17	0.3	0.48	0.73	0.88	0.95	1	N-P	N-P - naso-pharyng		
6	0.2	0.08	0.08	0.08	0.08	0.08	0.08	0.03	0	T-B	T-B - tracheo-bronc		
7	0.6	0.5	0.35	0.25	0.17	0.09	0.05	0.02	0	P	P - pulmonary regior		
8													
9	D(0.2)/D(1)	D(0.2)/D(1)	D(0.5)/D(1)	D(1)/D(1)	D(2)/D(1)	D(5)/D(1)	D(10)/D(1)	D(20)/D(1)	D(100)/D(1)		f -fraction of the CD		
10	=A5/$D5	=B5/$D5	=C5/$D5	=D5/$D5	=E5/$D5	=F5/$D5	=G5/$D5	=H5/$D5	=I5/$D5	N-P	D(AMAD) - depositi		
11	=A6/$D6	=B6/$D6	=C6/$D6	=D6/$D6	=E6/$D6	=F6/$D6	=G6/$D6	=H6/$D6	=I6/$D6	T-B			
12	=A7/$D7	=B7/$D7	=C7/$D7	=D7/$D7	=E7/$D7	=F7/$D7	=G7/$D7	=H7/$D7	=I7/$D7	P			
13													
14													
15													
16													
17						<AMAD = 0.1 um ----				<AMAD = 0.2 um ---			
18			Organ DCF					Organ DCF	DCF Ratio			Organ DCF	DCF Ratio
19		Organ	1 um	Region	f	D(0.1)/D(1)	fD(0.1)/D(1)	0.1 um	0.1 um/1 um	D(0.2)/D(1)	fD(0.2)/D(1)	0.2 um	0.2 um/1 um
20													
21		Gonads		N-P	0.26	0.333333333333333	=$E21*F21			0.166666666666667	=$E21*K21		
22				T-B	0.32	2.5	=$E22*F22			1	=$E22*K22		
23				P	0.42	2.4	=$E23*F23			2	=$E23*K23		
24			0.0000077			H(0.1)/H(1) --->	=SUM(G21:G23)	=$C24*G24		H(0.2)/H(1) --->	=SUM(L21:L23)	=$C24*L24	
25													
26		R Marrow		N-P	0.26	0.333333333333333	=$E26*F26			=$B$10	=$E26*K26		
27				T-B	0.32	2.5	=$E27*F27			=$B$11	=$E27*K27		
28				P	0.42	2.4	=$E28*F28			=$B$12	=$E28*K28		
29			0.000023			H(0.1)/H(1) --->	=SUM(G26:G28)	=$C29*G29		H(0.2)/H(1) --->	=SUM(L26:L28)	=$C29*L29	
30													
31		Bone Surf		N-P	0.26	0.333333333333333	=$E31*F31			0.166666666666667	=$E31*K31		
32				T-B	0.32	2.5	=$E32*F32			1	=$E32*K32		
33				P	0.42	2.4	=$E33*F33			2	=$E33*K33		
34			0.000072			H(0.1)/H(1) --->	=SUM(G31:G33)	=$C34*G34		H(0.2)/H(1) --->	=SUM(L31:L33)	=$C34*L34	
35													
36		Liver		N-P	0.26	0.333333333333333	=$E36*F36			=$B$10	=$E36*K36		
37				T-B	0.32	2.5	=$E37*F37			=$B$11	=$E37*K37		
38				P	0.42	2.4	=$E38*F38			=$B$12	=$E38*K38		
39			0.000031			H(0.1)/H(1) --->	=SUM(G36:G38)	=$C39*G39		H(0.2)/H(1) --->	=SUM(L36:L38)	=$C39*L39	
40													
41		Sum	=C29+C34+C39+C24					=H29+H34+H39+H24	=H41/$C41			=M29+M34+M39+M24	=M41/$C41
42													
43													
44													
45													
46													

Figure II-28. Image of Excel Spreadsheet Showing the Example of Formulas (for Neptunium-237) Used to Calculate Inhalation DCF Ratios

Microsoft Excel - Inhalation of large particles 10_12_02

Summary of the DC ratios for particles of various AMAD as compared with the 1 μm particles

Radionuclide/AMA	0.1	0.2	0.5	1	2	5	10	20	100
Chlorine-36	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Selenium-79	1.9	1.5	1.2	1.0	0.9	0.9	0.9	0.9	0.8
Strontium-90	1.7	1.2	1.0	1.0	1.1	1.2	1.3	1.3	1.2
Technetium-99	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Tin-126	2.3	1.9	1.4	1.0	0.7	0.5	0.3	0.2	0.1
Iodine-129	1.4	1.0	1.0	1.0	1.2	1.4	1.6	1.6	1.6
Cesium-135	1.5	1.0	1.0	1.0	1.1	1.4	1.6	1.5	1.5
Cesium-137	1.5	1.0	1.0	1.0	1.1	1.4	1.6	1.6	1.5
Lead-210	1.7	1.2	1.0	1.0	1.1	1.2	1.3	1.2	1.2
Radium-226	2.3	1.9	1.4	1.0	0.7	0.5	0.3	0.2	0.1
Actinium-227	1.8	1.3	1.1	1.0	1.0	1.1	1.2	1.1	1.1
Thorium-229	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Thorium-230	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Thorium-232	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Protactinium-231	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Uranium-232	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-233	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-234	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-236	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Uranium-238	2.4	2.0	1.4	1.0	0.7	0.4	0.2	0.1	0.0
Neptunium-237	1.9	1.2	1.1	1.0	1.0	1.1	1.2	1.0	0.9
Plutonium-238	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-239	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-240	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Plutonium-242	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Americium-241	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8
Americium-243	1.9	1.2	1.1	1.0	1.0	1.1	1.1	0.9	0.8

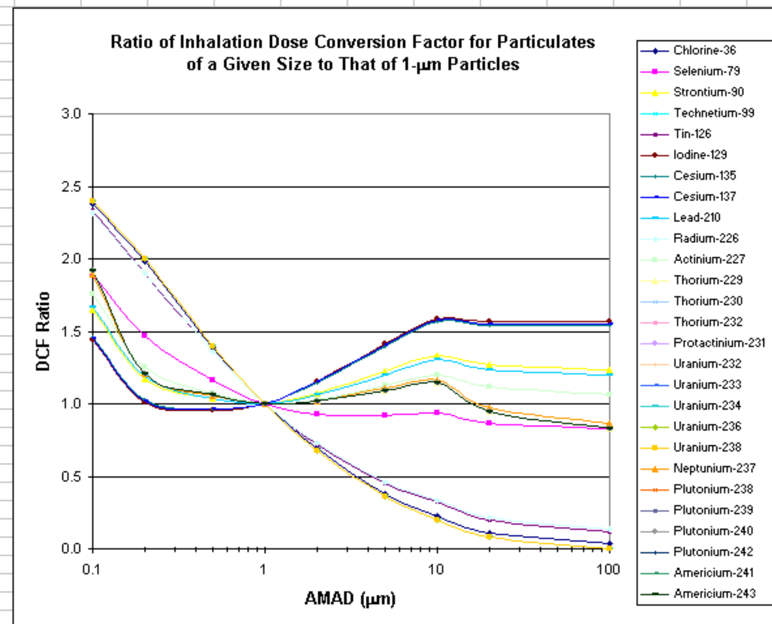

Figure II-29. Image of Excel Spreadsheet Showing Summary of Inhalation DCF Ratios for 0.1 to 100 μm Particles

ATTACHMENT III

FILES SUPPORTING THE ANALYSIS AND CD-ROM

The following Excel files were used in this analysis and are provided on the CD-ROM:

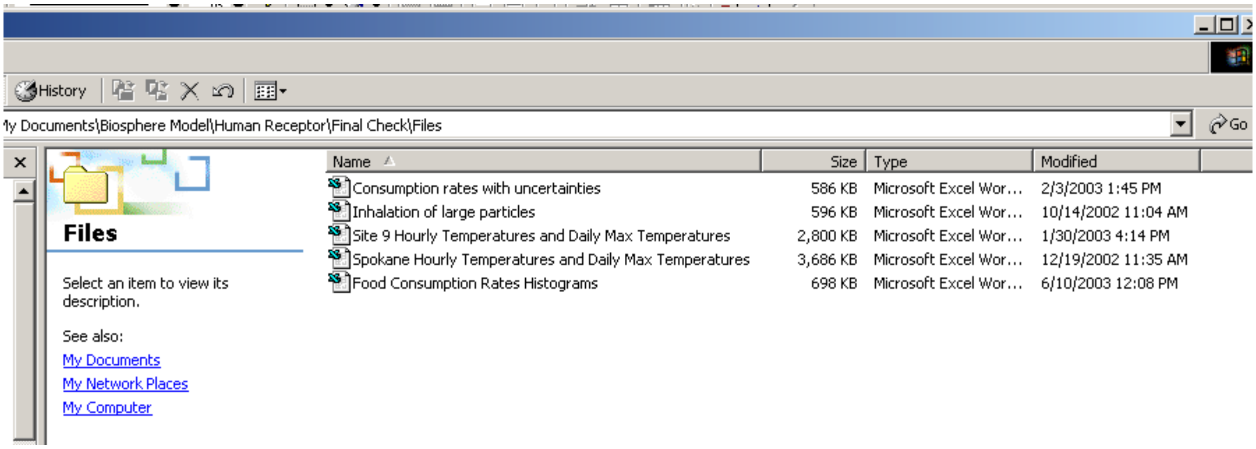

Figure III-1. List of Files Included on CD-ROM