USER GUIDE TO DCFPAK 2.2

K. F. Eckerman[1] and R. W. Leggett[2]

Oak Ridge National Laboratory
1060 Commerce Park
Oak Ridge, Tennessee 37831, USA

[1]phone: 865-574-6251
fax: 865-574-9888
e-mail: kfe@ornl.gov

[2]phone: 865-576-2079
fax: 865-574-9888
e-mail: rwl@ornl.gov

USER GUIDE TO DCFPAK 2.2

ABSTRACT

The software and data package DCFPAK (Dose Coefficient Package) allows electronic access to compilations of dose coefficients, risk coefficients, and other data used in radiation protection. DCFPAK has been built in a series of versions designed to allow access to expanded capabilities as they are completed. This report is a guide to a new version called DCFPAK 2.2 that provides electronic access to the following data: detailed nuclear decay data for 1252 radionuclides; age-independent skin dose coefficients for each of these 1252 radionuclides; age-specific ingestion dose coefficients for each of 737 of those 1252 radionuclides, based on biokinetic and dosimetric models applied in Federal Guidance Report No. 13 (FGR13); age-specific inhalation dose coefficients for each of these 737 radionuclides inhaled as particulate aerosols with arbitrary particle size distribution, based on models of FGR13; external dose rate coefficients for each of the full set of 1252 radionuclides based on models of Federal Guidance Report No. 12 (FGR12) for adults; and age- and gender-averaged cancer mortality risk coefficients for each of the internal exposure scenarios addressed and selected external exposure scenarios.

INTRODUCTION

The software and data package DCFPAK 2.2 (Dose Coefficient Package) allows electronic access to dose and risk coefficients for exposures to radionuclides in the environment. DCFPAK has been built in a series of versions designed to allow access to expanded capabilities as they are completed. Seven versions were built from 1996 through 2007, with DCFPAK 1.8 (August, 2007) being the latest comprehensive software package. DCFPAK 1.8 provides access to the following information for each of 737 radionuclides:

- Detailed nuclear decay data.
- Inhalation and ingestion dose coefficients (committed equivalent dose) for adults summarized in Federal Guidance Report No. 11 (FGR11) (EPA, 1988).
- External dose rate coefficients for adults as tabulated in Federal Guidance Report No. 12 (FGR12) (EPA, 1993).
- Age-specific dose coefficients (committed equivalent dose and 30-d absorbed dose) for inhalation and ingestion based on biokinetic and dosimetric models applied in Federal Guidance Report No.13 (FGR13) (EPA, 1999); these are generally the same models as applied in current documents of the International Commission on Radiological Protection (ICRP).
- Age- and gender-averaged cancer mortality risk coefficients for inhalation, ingestion, and external exposure based on models and methods of FGR13.

For the inhalation case, dose and risk coefficients based on models of FGR13 are provided in DCFPAK 1.8 for each of three levels of solubility of inhaled particles: relatively soluble (Type F), moderately soluble (Type M), and relatively insoluble (Type S). For each radionuclide and absorption type, dose and risk coefficients are provided for each of the following lognormally distributed particle sizes, expressed as activity median aerodynamic diameter (AMAD): 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 5, 10, and 30 μm. Additionally, dose coefficients for inhaled radionuclides are provided for each of the following monodispersed particle sizes, expressed as aerodynamic diameter: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 5, 10, 30, 50, and 100 μm.

The present report describes an updated version of DCFPAK called DCFPAK 2.2 that further expands the DCFPAK capabilities. DCFPAK 2.2 provides electronic access to the following information:

- Summary information on the decay data for 1252 radionuclides.
- Age-independent skin dose coefficients for each of the 1252 radionuclides.
- Age-specific ingestion dose coefficients (committed equivalent dose and 30-d absorbed dose) for each of the 737 radionuclides addressed in DCFPAK 1.8, based on biokinetic and dosimetric models applied in FGR13.
- Age-specific inhalation dose coefficients (committed equivalent dose and 30-d absorbed dose) for each of 737 radionuclides in aerosol forms with any user-specified particle size distribution, based on models of FGR13.
- External dose rate coefficients for each of the 1252 radionuclides based on the methods of FGR12 (the coefficients are calculated for adults but are applicable to all age groups).

- Age- and gender-averaged cancer mortality risk coefficients for each of the internal exposure scenarios addressed and selected external exposure scenarios.

DCFPAK 2.2 is distributed as a Windows installation procedure[1] that installs the software DCFPAK2 and its data files. The install procedure creates a folder with the default name DCFPAK2 on the hard drive, installs the software in the folder, and places the DCFPAK2 icon on the desktop. Three additional folders, below the main folder, are created. The data files reside in the subfolder DATA and all output files generated by the software are written to the subfolder OUTPUT. User-defined files characterizing an aerosol in a histogram manner are to reside in the subfolder INPUT.

DCFPAK2 is a console application developed using PowerBASIC™ Console Compiler[2] with Perfect Sync, Inc[3] modules Console Tools™ and Graphics Tools™ providing additional functionality. Files created by DCFPAK2 have the extension TXT and are viewed within the software by the ASCII editor the user has associated with files of this extension, e.g., Microsoft's Notepad. This document, as a PDF, is viewed assuming the user has associated files with file extension PDF with Acrobat Reader[4].

The DCFPAK 2.2 data library is based on state-of-the-art models and methods and does not include the older dose coefficients summarized in FGR11. Those coefficients are available in DCFPAK 1.8.

Throughout this report, the terms "user-specified particle size distribution" and "arbitrary particle size" are used interchangeably to mean any distribution of aerodynamic diameters within the bounds 0.0001 to 200 μm.

BACKGROUND: PREVIOUS VERSIONS OF DCFPAK

This section summarizes the different versions of DCFPAK that have been developed. User guides for the different versions can be obtained from the authors.

DCFPAK 1.0

In a project conducted in the mid-1990s and supported by Sandia National Laboratories (SNL), ORNL developed a software and data package called DCFPAK (Dose Coefficient File Package, Eckerman and Leggett, 1996) and referred to in this report as DCFPAK 1.0. The purpose was to provide rapid access to published compilations of dose coefficients for internal or external exposure to radionuclides.

DCFPAK 1.0 consists of libraries of derived estimates of dose per unit exposure to radionuclides and a driver code that allows interactive examination of the dose estimators for any of several exposure scenarios and ~800 radionuclides. DCFPAK 1.0 includes the dose coefficients summarized in Federal Guidance Report No. 11 (FGR11) (EPA, 1988)

---

[1] The install package was created using Inno Setup compiler available from http://www.innosetup.com.
[2] PowerBASIC, Inc.; 1978 Tamiami Trail S. #200; Venice, FL 34293. See http://www.powerbasic.com/.
[3] Perfect Sync, Inc. 6511 Franklin Woods Dr., Traverse City, MI. See http://perfectsync.com/.
[4] Adobe Acrobat Reader of Adobe Inc. is available from http://www.pdf-2007.com/index.asp.

and Federal Guidance Report No. 12 (FGR12) (EPA, 1993). FGR11 provides dose coefficients in the form of 50-year integrated dose equivalents for acute ingestion or acute inhalation of radionuclides by workers, based on the biokinetic and dosimetric models of ICRP Publication 30 (1979, 1980, 1981, 1988). FGR12 provides dose coefficients in the form of dose per unit time-integrated exposure for external exposure of an adult to radionuclides in air, water, or soil. DCFPAK 1.0 includes coefficients for all organs addressed in FGR11 and FGR12 plus values for additional organs. DCFPAK 1.0 also determines the decay chain of a radionuclide, truncates the chain after the last potentially significant decay chain member, and assembles the dose coefficients for all potentially significant chain members. For each radionuclide and exposure mode, DCFPAK 1.0 libraries include both the effective dose equivalent, H_E, based on the tissue weighting factors given in ICRP Publication 26 (1977), and the effective dose, E, based on tissue weighting factors given in ICRP Publication 60 (1991) (Table 1).

RDCPAK

In a later (1999) project also supported by SNL, ORNL developed a separate software package called RDCPAK as a preliminary effort to provide electronic access to the risk coefficients tabulated in FGR13 as well as age-specific dose coefficients based on the newer biokinetic and dosimetric models and methods used in that document (ICRP, 1989, 1993, 1994, 1995a, 1995b, 1996). A report on the RDCPAK package was written for SNL's internal use. For development of age-specific dose coefficients, the following ages at acute intake are considered in RDCPAK: infant (100 days old), 1 y, 5 y, 10 y, 15 y, and adult. The dose coefficients in RDCPAK represent 50-year cumulative dose equivalent for intake by an adult and cumulative dose equivalent to age 70 years for intake by a child. For completeness, RDCPAK includes dose coefficients for the external exposure scenarios considered in DCFPAK 1.0 but not addressed in FGR13: immersion in water and external exposure to soil contaminated to a depth of 1, 5, or 15 cm. In all, dose coefficients for each of 23 tissues are provided for 10 internal or external exposure scenarios. The tissues considered are the same as those addressed in DCFPAK 1.0. These tissues are listed in Table 2, which also shows the tissues that are addressed in DCFPAK 1.0 and RDCPAK but are not addressed in the federal guidance reports.

DCFPAK 1.2

In 2005, SNL and ORNL entered into a joint project, initially supported by the Technology Integration (TI) Program of the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE), to develop a software and data package that merges and extends the capabilities of DCFPAK 1.0 and RDCPAK. The purpose of the project is to provide a more comprehensive, flexible, and accurate radiological database for rapid assessment of responder or public doses during radiological emergencies, including malicious uses of radioactive material that were not considered when the original software packages were developed. Deficiencies identified in DCFPAK 1.0 and RDCPAK include inaccuracies in nuclear decay data and dose coefficients based on those data, incomplete or outdated information for some radionuclides considered likely candidates for Radiological Dispersal Devices (RDDs) such as ^{252}Cf, lack of dose coefficients suitable for assessing short-term consequences, and lack of dose coefficients for distributions of particle sizes that might be generated by RDDs.

The updated package has been built in phases with the intent of allowing access to expanded capabilities soon after they are developed. The end product of each phase is an updated version of DCFPAK.

The first version of DCFPAK developed in the present project is called DCFPAK 1.2. DCFPAK 1.2 corrects and expands the data libraries in DCFPAK 1.0. These libraries are based on the models and methods of ICRP Publication 30 (1979, 1980, 1981, 1988) and the tabulations of dose coefficients in FGR11 and FGR12.

Table 1. Tissue weighting factors given in ICRP Publication 26 (1977) and ICRP Publication 60 (1991)[a]

Organ or tissue	Tissue weighting factor (w_T)	
	ICRP Pub. 26	ICRP Pub. 60
Gonads	0.25	0.20
Bone marrow (red)	0.12	0.12
Colon	--	0.12
Lung	0.12	0.12
Stomach	--	0.12
Urinary bladder	--	0.05
Breast	0.15	0.05
Liver	--	0.05
Esophagus	--	0.05
Thyroid	0.03	0.05
Skin	--	0.01
Bone surface	0.03	0.01
Remainder	0.30	0.05

[a]The values were developed for a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and to either sex.

The nuclear decay data used to develop the dose and risk coefficients in FGR11, FGR12, and FGR13, and hence those in DCFPAK 1.0 and RDCPAK, were taken from ICRP Publication 38 (1983). Updated information has revealed a number of cases in which radionuclides were incorrectly identified in ICRP Publication 38 due to uncertainty as to whether reported measurements represented ground state or excited state. Also, substantially different physical half-lives are now estimated for some long-lived radionuclides. One of the main objectives for DCFPAK 1.2 was to correct these problems in the ICRP Publication 38 database and associated problems in the existing DCFPAK and RDCPAK databases, which represent the starting point for the updated software and data package. Table 3 lists radionuclides for which the identification in the ICRP Publication 38 database has now been changed. Table 4 summarizes changes of physical half-lives in the ICRP Publication 38 database.

For the five radionuclides listed in Table 5, radiations associated with spontaneous fission represent an important contribution to dose coefficients for ingestion, inhalation, or external exposure. Radiations associated with spontaneous fission were not reflected in the external dose coefficients for these radionuclides in FGR12 and hence were not reflected in the external dose coefficients provided in DCFPAK 1.0. The external dose coefficients provided in DCFPAK 1.2 reflect the contribution of radiations associated with spontaneous fission. Also, the dose coefficients for ingestion or inhalation of these radionuclides provided in DCFPAK 1.2 are based on updated nuclear decay data.

DCFPAK 1.0 provides inhalation dose coefficients only for particle size 1 µm (AMAD). DCFPAK 1.2 provides inhalation dose coefficients for each of 10 particle sizes: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 5, and 10 µm (AMAD).

Table 2. Tissues addressed in DCFPAK 1.0 and 1.1 and in Federal Guidance Reports

Tissue	DCFPAK 1.0 and 1.1	As cancer site in FGR13[a]	FGR11[e]	FGR12[e]
Adrenal	Yes	b	No	No
Urinary Bladder	Yes	Yes	No	No
Bone Surface	Yes	Yes	Yes	Yes
Brain	Yes	No	No	No
Breast	Yes	Yes	Yes	Yes
Esophagus	Yes	Yes	No	No
Stomach	Yes	Yes	No	No
Small Intestine	Yes	No	No	No
Upper Large Intestine	Yes	c	No	No
Lower Large Intestine	Yes	c	No	No
Kidney	Yes	Yes	No	No
Liver	Yes	Yes	No	No
Lung	Yes	Yes	Yes	Yes
Muscle	Yes	b	No	No
Ovaries	Yes	Yes	No	No
Testes	Yes	No	No	No
Gonad	No	No	Yes	Yes
Pancreas	Yes	b	No	No
Red Marrow	Yes	Yes	Yes	Yes
Skin	Yes	Yes	No	Yes
Spleen	Yes	No	No	No
Thymus	Yes	No	No	No
Thyroid	Yes	Yes	Yes	Yes
Uterus	Yes	No	No	No
Remainder[d]	No	No	Yes	Yes

a - A risk coefficient refers to all cancers combined but is based on estimated cancers for individual tissues.
b - Estimated “residual” cancers based on doses to muscle, pancreas, and adrenals.
c - Estimates for colon cancer based on doses to upper and lower large intestines.
d - Represents multiple tissues considered explicitly in DCFPAK 1.0 and 1.1.

Table 3. Radionuclides incorrectly identified in ICRP Publication 38 or later renamed

As given in ICRP Pub. 38		Correction	
Nuclide	$T_{1/2}$	Nuclide	$T_{1/2}$
Nb-89a	66m	Nb-89m	66m
Nb-89b	122m	Nb-89	2.03h
In-110a	69.1m	In-110m	69.1m
In-110b	4.9h	In-110	4.9h
Sb-120a	15.89m	Sb-120	15.89m
Sb-120b	5.76d	Sb-120m	5.76d
Sb-128a	10.4m	Sb-128m	10.4m
Sb-128b	9.01h	Sb-128	9.01h
Eu-150a	12.62h	Eu-150m	12.8h
Eu-150b	34.2y	Eu-150	36.9y
Ta-178a	9.31m	Ta-178	9.31m
Ta-178b	2.2h	Ta-178m	2.36h
Re-182a	12.7h	Re-182m	12.7h
Re-182b	64.0h	Re-182	64.0h
Ir-186a	15.8h	Ir-186	16.64h
Ir-186b	1.75h	Ir-186m	1.92h
Np-236a	115E3y	Np-236	1.54E5y
Np-236b	22.5h	Np-236m	22.5h

Table 4. Half-life corrections

Nuclide	Half-life given in ICRP Pub. 38	Correction
Te-123	1E13y	6E14y
Fe-60	1E5y	1.5E6y
Se-79	6.5E4y	2.95E5y
Ag-108m	127y	418y
Sn-126	1E5y	2.30E5
Hg-194	260y	440y
Ti-44	47.3y	60.0y
Cm-250	6900y	8300y
Rh-102m	207d	3.742y
In-115	5.1E15y	4.4E14y
Pb-202	3.0E5y	5.25E4
Si-32	450y	132y
Tb-157	150y	71y
Ca-41	1.4E5	1.02E5y

Table 5. Spontaneous fission nuclides

Nuclide	SF Branching (%)
Pu-244	0.121
Cm-248	8.39
Cm-250	74.0
Cf-252	3.092
Cf-254	99.69

DCFPAK 1.4

The second version of DCFPAK developed in the present project is called DCFPAK 1.4. This version merges DCFPAK 1.2 with the dosimetric portion of RDCPAK, i.e., it includes the age-specific dose coefficients based on models applied in FGR13 but does not include risk coefficients. The driver code for DCFPAK 1.4 gives the option of using dose coefficients based on FGR11 and FGR12 or dose coefficients based on FGR13. In addition to the database corrections indicated above for DCFPAK 1.2, DCFPAK 1.4 provides 30-day cumulative absorbed doses for ingestion and inhalation. The original plan was to include 30-day doses for the inhalation case only for 1-μm particles and to add 30-day doses for the other nine particles in the next phase of the project. As it turned out, it was convenient to derive 30-day doses for all 10 of the particle sizes that had been considered in DCFPAK 1.2 during the development of the database for DCFPAK 1.4. Hence, 30-d doses for each of these 10 particle sizes were included in the DCFPAK 1.4 data libraries.

DCFPAK 1.6

The third version of the package developed in the present project is called DCFPAK 1.6. This version includes all capabilities of DCFPAK 1.2 and DCFPAK 1.4 and extends DCFPAK 1.4 by including risk coefficients based on the methods and models of FGR13 but including values for all 10 particle sizes addressed in DCFPAK 1.2. (Risk coefficients are given in FGR13 only for 1 μm AMAD). Also, DCFPAK 1.6 provides a default inhalation absorption type for each radionuclide for use when information on the form of the inhaled radionuclide is not available.

DCFPAK 1.8

The fourth version of the package developed in the present project is called DCFPAK 1.8. That version includes all of the capabilities of DCFPAK 1.6 and improves DCFPAK 1.6 by adding:

- Inhalation dose coefficients for a relatively large polydispersed particle size (30 μm AMAD).
- Inhalation dose coefficients for 13 monodispersed particle sizes: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 5, 10, 30, 50, and 100 μm (aerodynamic diameter).

Thirty-day absorbed dose coefficients as well as committed equivalent dose coefficients are provided for each particle size and each form of each radionuclide addressed.

DCFPAK 2.0

In contrast to earlier versions, DCFPAK 2.0 is not a software package and does not include all datasets included in the preceding version (DCFPAK 1.8). Rather, DCFPAK 2.0 consists of a set of tools needed to add the capability to DCFPAK 1.8 or other radiation risk assessment package of addressing inhaled radioactive material of arbitrary particle size. Specifically, DCFPAK 2.0 provides the data sets and algorithms needed to calculate age-specific dose and risk coefficients for inhaled radionuclides carried in aerosols of arbitrary particle size, based on models of FGR13. The term "arbitrary particle size" is defined as any fixed (monodispersed) size or any distribution of sizes within the bounds 0.0001 to 200 µm (aerodynamic diameter).

DCFPAK 2.0 is described here in greater detail than other previous versions of DCFPAK for two reasons. First, DCFPAK 2.0 differs in nature from other versions of DCFPAK because it is a method of calculation of dose and risk coefficients based on a data library, while other versions of DCFPAK simply allow the reader to read information contained in a data library. Second, the background information described below is needed to understand the descriptions of certain data files in the DCFPAK 2.2 library.

As a starting place it is useful to review features of the ICRP's Human Respiratory Tract Model (HRTM) (ICRP, 1994). The structure of the HRTM is shown in Figure 1. The model divides the respiratory system into extrathoracic (ET) and thoracic regions. The airways of the ET region are further divided into two categories: the anterior nasal passages (ET_1), in which deposits are removed by extrinsic means such as nose blowing, and the posterior nasal passages (ET_2) including the nasopharynx, oropharynx, and the larynx, from which deposits are swallowed. The airways of the thorax include the bronchi (compartments labeled BB_i), bronchioles (compartments labeled bb_i), and alveolar region (compartments labeled AI_i). Material deposited in the thoracic airways may be cleared into blood by absorption, to the gastrointestinal (GI) tract by mechanical processes (that is, transported upward and swallowed), and to the regional lymph nodes via lymphatic channels.

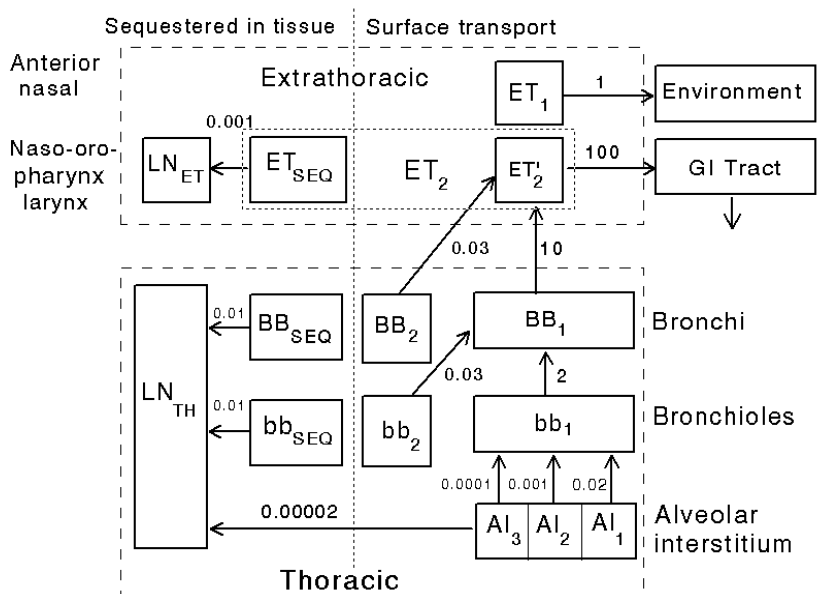


Figure 1. Structure of the ICRP's Human Respiratory Tract Model (ICRP, 1994).

Reference particle transport rates, also called mechanical clearance rates, are shown beside the arrows in Figure 1. These values are in units of d^{-1}. For example, particle transport from bb_1 to BB_1 is assumed to occur at a fractional rate of 2 d^{-1}, and particle transport from ET_2' to the GI tract is assumed to occur at a fractional rate of 100 d^{-1}.

For an inhaled compound, the mechanical clearance of a radionuclide carried in particles is in competition with its clearance by absorption to blood following dissolution of the particles. The rate of clearance of a radionuclide from the respiratory tract by absorption to blood depends on the element and the physical and chemical form in which it is inhaled. Although the model permits consideration of compound-specific dissolution rates, a radionuclide in particulate form generally is assigned to one of three default absorption types: Type F, representing fast dissolution and a high level of absorption to blood; Type M, representing an intermediate rate of dissolution and an intermediate level of absorption to blood; and Type S, representing slow dissolution and a low level of absorption to blood.

It is assumed that regional deposition of inhaled material in the respiratory tract is independent of the absorption type but dependent on particle size, age at intake, and the level of physical activity of the exposed individual. In the derivation of dose or risk coefficients for an inhaled radionuclide, regional deposition in the respiratory tract is based on reference 24-hour average levels of activity for different ages at intake, reducing the variables to age and particle size.

Regional deposition of inhaled material in the respiratory tract is defined by the fractions of the inhaled material deposited in each of the following nine regions of the tract:

Region 1. AI (alveolar intersitium – boxes $AI_1 + AI_2 + AI_3$ in Figure 1);
Region 2. bbe-gel (fast-moving mucus in bronchioles – box bb_1);
Region 3. bbe-sol (slow-moving mucus in bronchioles – box bb_2);
Region 4. bbe-seq (sequestered material in bronchioles – box bb_{SEQ});
Region 5. BBi-gel (fast-moving mucus in bronchi – box BB_1);
Region 6. BBi-sol (slow-moving mucus in bronchi – box BB_2);
Region 7. BBi-seq (sequestered material in bronchi – box BB_{SEQ});
Region 8. ET_1 (anterior nasal passages – box ET_1);
Region 9. ET_2 (posterior nasal passages – dashed box ET_2).

Fixed fractions of deposition in AI are assigned to its subcompartments AI_1, AI_2, and AI_3, and fixed fractions of deposition in ET_2 are assigned to its subcompartments ET_2' and ET_{SEQ}.

The data files required to generate dose and risk coefficients for arbitrary particle sizes include:

- Nine files of age-specific 30-d absorbed dose coefficients (these files have extension INT).
- Nine files of age-specific committed equivalent dose coefficients (these files have extension HDB).
- Nine files of age- and gender-averaged cancer risk coefficients (these files have extension RBS).

Each of these files is derived under the assumption of unit deposition (1 Bq) of an inhaled radionuclide in one of the nine regions defined above, with no deposition in any of the other eight regions. For example, a file named AI.INT contains age-specific 30-d absorbed dose coefficients based on deposition of 1 Bq of a radionuclide of a given absorption type in AI (Region 1) and no deposition in the other nine regions; a file named bbe-gel.INT contains 30-d absorbed dose coefficients based on deposition of 1 Bq in bbe-gel (Region 2) and no deposition in the other eight regions, and so forth.

The library contains two other files needed to derive dose and risk coefficients for arbitrary particle sizes:

- A file named DCFPAK2.DEP lists age-specific fractional deposition in Regions 1-9 for each of 50 particle sizes. This file is used to derive age-specific deposition fractions in each of the nine regions for an arbitrary particle size, for the purpose of calculating dose coefficients.
- A file called RISKCOEF.DEP lists average deposition fractions in Regions 1-9 over each of four age ranges for each of 35 particle sizes. This file is used to derive age-group-specific deposition fractions in each of the nine regions for an arbitrary particle size, for the purpose of calculating risk coefficients.

A dose or risk coefficient for acute inhalation of a radionuclide of any particle size can be calculated as a combination of dose or risk coefficients read from the corresponding nine "regional deposition" files. For example, if the fractions of inhaled material deposited in Regions 1, 2, …, 9 for a given particle size at the m-th age addressed in the files are $p_{1,m}$, $p_{2,m}$ …, $p_{9,m}$, respectively, then the 30-d absorbed dose coefficient $D_{k,m}$ for Tissue k and Age m is calculated as

$$D_{k,m} = p_{1,m}d_{1,k,m} + p_{2,m}d_{2,k,m} + \ldots\ p_{9,m}d_{9,k,m}$$

where $d_{j,k,m}$ is the 30-d absorbed dose coefficient for Tissue k based on unit acute deposition in Region j at Age m, read from the "INT" based on unit deposition in Region j. Similarly, committed equivalent dose coefficients for specific tissues are calculated as linear combinations of values from the nine "HDB" files. Determination of effective dose coefficients or risk coefficients from the regional deposition files requires more complicated algorithms due to nonlinearities in the derivations of these quantities.

CAPABILITIES OF DCFPAK 2.2

The present report describes an updated version of DCFPAK called DCFPAK 2.2 that further expands the DCFPAK database and capabilities. DCFPAK 2.2 provides electronic access to the following information:

1. Summary information on the nuclear decay data for 1252 radionuclides.
2. Tabulation of the serial decay of radionuclides forming radioactive progeny.
3. Age-independent skin dose coefficients for each of these 1252 radionuclides.

4. Age-specific ingestion dose coefficients for each of the 737 radionuclides addressed in DCFPAK 1.8, based on biokinetic and dosimetric models applied in FGR13.
5. Age-specific inhalation dose coefficients for each of the 737 radionuclides carried in aerosols with a user-specified particle size distribution, based on models of FGR13.
6. Age-specific inhalation dose coefficients for vapor and gaseous forms of selected radionuclides based on models of FGR 13.
7. External dose rate coefficients for 1252 radionuclides based on the methods of FGR12 for adults.
8. Age- and gender-averaged cancer mortality risk coefficients for each internal and external exposure scenarios addressed in FGR 13.

The dose and risk coefficients provided in DCFPAK 2.2 for inhalation or ingestion of each of 737 radionuclides were based on nuclear decay data of ICRP Publication 38 (1983) as corrected in DCFPAK 1.2. The dose and risk coefficients for external exposure and items 1-3 above contained in DCFPAK 2.2 were based on the nuclear decay database developed by Endo et al (2005a, 2005b, 2007) and published by Eckerman and Endo (2008) and by the ICRP (2008). From a dosimetric standpoint the nuclear decay data of Publication 38 does not differ significantly from the updated nuclear decay data for the same radionuclides.

THE DCFPAK 2.2 DATA LIBRARY

Except for text files, the files of the library are formatted direct-access files consisting of ASCII characters, with all records in a given file of the same length and each record ending with an ASCII carriage-return (CR) and line-feed (LF) character. The data are in SI units. Equivalent and effective dose coefficients are in sievert (Sv), absorbed dose coefficients in gray (Gy), activity in becquerel (Bq), time in seconds (s), length in meters (m), and mass in kilogram (kg). With the exception of DCFPAK2.NDX the files are self-documenting. DCFPAK2.NDX is described in detail in Appendix A. The data files are summarized below.

DCFPAK2.NDX

This is the master index file. It contains the name and half-life of each radionuclide addressed in DCFPAK 2.2 and pointers to the radionuclide's records in all other files in the library. It also contains information on the different inhaled and ingested forms of the radionuclide addressed in DCFPAK 2.2. Further details are given in Appendix A.

DCF_INGS.DAT

This file contains age-specific dose coefficients for the case of acute ingestion of radionuclides. The coefficients are based on the models and methods detailed in FGR13 and are given for infant (age 100 d), 1-, 5-, 10-, and 15-y-old, and adult. The coefficients represent the committed equivalent dose in various tissues over a 50-year period following intake (Sv Bq^{-1} inhaled) for adults and to age 70 y for children. The effective dose coefficient in these files is based on the radiation weighting factors of ICRP Publication 60 (1991).

DCF_INGS.D30

This file contains age-specific dose coefficients representing the absorbed dose delivered within 30 days following acute ingestion of a radionuclide. The absorbed dose coefficients (Gy Bq^{-1} inhaled) are presented separately for low LET (linear energy transfer) radiations (electrons and photons) and for high LET radiations (alpha particles, neutrons and fission fragments). The coefficients are based on the models and methods detailed in FGR13 and are given for infant, 1-, 5-, 10-, and 15-y-old, and adult.

DCFVAPOR.DAT

This file contains age-specific dose coefficients for the case of acute inhalation of radionuclides in vapor or gaseous forms. The coefficients are based on the models and methods detailed in FGR13 and are given for infant (age 100 d), 1-, 5-, 10-, and 15-y-old, and adult. The coefficients represent the committed equivalent dose in various tissues over a 50-year period following intake (Sv Bq^{-1} inhaled) for adults and to age 70 y for children. The effective dose coefficient in these files is based on the radiation weighting factors of ICRP Publication 60.

DCFVAPOR.D30

This file contains age-specific dose coefficients representing the absorbed dose delivered within 30 days following acute inhalation of radionuclides in vapor or gaseous forms. The absorbed dose coefficients (Gy Bq^{-1} inhaled) in this file are all associated with low LET radiations (electrons and photons). Coefficients are based on the models and methods detailed in FGR13 and are given for infant, 1-, 5-, 10-, and 15-y-old, and adult.

FGR12III_N.DAT

These seven files contain dose rate coefficients for the case of external exposure to the radionuclide in environmental media. "N" in the file name denotes the external exposure mode: N = 1 for air submersion, 2 for water immersion, 3 for standing on contaminated ground surface, 4 for standing on soil contaminated to 1 cm depth, 5 for standing on soil contaminated to 5 cm, 6 for standing on soil contaminated to 15 cm, and 7 for standing on soil contaminated to an infinite depth. The coefficients are based on the methods described in FGR12 and represent the dose per time-integrated activity concentration in the environmental media. The unit of dose is sievert (Sv), and time is in seconds (s). For air submersion (F31) and water immersion (F32) the unit of activity concentration is Bq m^{-3}. For activity on the ground surface (F33) it is Bq m^{-2}, and for activity extending to a specified depth in soil (F34, F35, F36, and F37) the unit is Bq m^{-3}.

EXTRISK.RBS

This file contains population-averaged cancer mortality risk coefficients for submersion in a contaminated atmosphere, exposure to contaminated ground surface, and exposure to contaminated soil for 1252 radionuclides. The risk coefficients are based on the models and methods detailed in FGR 13 and represent the probability of radiogenic cancer mortality per unit time integrated activity in the air, on the ground surface, and within the soil volume. For air submersion the units are m^3 (Bq s)$^{-1}$, for ground surface they are m^2 (Bq s)$^{-1}$ and for soil volume kg (Bq s)$^{-1}$. The risk coefficients correspond to N=1, 3, and 7 in the above discussion of the FGR12III_N.DAT dose rate coefficient files.

DCF_INGS.RBS
This file contains population-averaged cancer mortality risk coefficients for the case of ingestion of radionuclides. The risk coefficients are based on the models and methods detailed in FGR13 and represent the probability of radiogenic cancer mortality per unit activity intake (Bq^{-1} ingested). Separate risk coefficients are provided for intake of a radionuclide in tap water and intake of the same radionuclide in diet. Differences in the two risk coefficients may arise because the calculation of a coefficient takes into account changes with age in intake of tap water and intake of total diet (i.e., total caloric intake), and because different gastrointestinal absorption fractions are applied to ingestion in tap water and ingestion in diet for a few radionuclides.

DCFVAPOR.RBS
This file contains population-averaged cancer mortality risk coefficients for the case of inhalation of radionuclides in vapor or gaseous forms. The risk coefficients are based on the models and methods detailed in FGR13 and represent the probability of radiogenic cancer mortality per unit activity intake (Bq^{-1} inhaled).

[REGION].INT
In the above generic file name, [REGION] represents one of the nine regions of the HRTM. These nine files contain age-specific 30-d absorbed dose coefficients for inhalation of radionuclides, based on the models and methods of FGR13. Each of these files is derived under the assumption of unit (1 Bq) deposition in one of nine regions of the HRTM (Regions 1-9: AI, bbe-gel, bbe-sol, bbe-seq, BBi-gel, BBi-sol, BBi-seq, ET_1, or ET_2), with no deposition in any of the other eight regions. For example, a file named BBE-GEL.INT contains age-specific 30-d absorbed dose coefficients based on deposition of 1 Bq in bbe-gel (Region 2) and no deposition in the other eight regions. All nine files are used by DCFPAK 2.2 to calculate an age-specific 30-d absorbed dose coefficient for inhalation of a radionuclide carried in a particulate aerosol of user-specified size, based on the derived distribution of the inhaled material among these nine regions of the respiratory tract. The full names of the nine files are AI.INT, BBE-GEL.INT, BBE-SOL.INT, BBE-SEQ.INT, BBI-GEL.INT, BBI-SOL.INT, BBI-SEQ.INT, ET1.INT, and ET2.INT.

[REGION].HDB
In the above generic file name, [REGION] represents one of the nine regions of the HRTM. These nine files contain age-specific committed equivalent dose coefficients for inhalation of radionuclides, based on the models and methods of FGR13. Each of these files is derived under the assumption of unit (1 Bq) deposition in one of nine regions of the HRTM (Regions 1-9: AI, bbe-gel, bbe-sol, bbe-seq, BBi-gel, BBi-sol, BBi-seq, ET_1, or ET_2), with no deposition in any of the other eight regions. For example, a file named BBE-GEL.HDB contains age-specific committed equivalent dose coefficients based on deposition of 1 Bq in bbe-gel (Region 2) and no deposition in the other eight regions. All

nine files are used by DCFPAK 2.2 to calculate an age-specific committed equivalent dose coefficient for inhalation of a radionuclide carried in a particulate aerosol of user-specified size, based on the derived distribution of the inhaled material among these nine regions of the respiratory tract. The full names of the nine files are AI.HDB, BBE-GEL.HDB, BBE-SOL.HDB, BBE-SEQ.HDB, BBI-GEL.HDB, BBI-SOL.HDB, BBI-SEQ.HDB, ET1.HDB, and ET2.HDB.

[REGION].RBS

In the above generic file name, [REGION] represents one of the nine regions of the HRTM. These nine files contain risk dose coefficients for inhalation of radionuclides, based on the models and methods of FGR13. Each of these files is derived under the assumption of unit (1 Bq) deposition in one of nine regions of the HRTM (Regions 1-9: AI, bbe-gel, bbe-sol, bbe-seq, BBi-gel, BBi-sol, BBi-seq, ET_1, or ET_2), with no deposition in any of the other eight regions. For example, a file named BBE-GEL.RBS contains risk coefficients based on deposition of 1 Bq in bbe-gel (Region 2) and no deposition in the other eight regions. All nine files are used by DCFPAK 2.2 to calculate a risk coefficient for inhalation of a radionuclide carried in a particulate aerosol of user-specified size, based on the derived distribution of the inhaled material among these nine regions of the respiratory tract. The full names of the nine files are AI.RBS, BBE-GEL.RBS, BBE-SOL.RBS, BBE-SEQ.RBS, BBI-GEL.RBS, BBI-SOL.RBS, BBI-SEQ.RBS, ET1.RBS, and ET2.RBS.

DCFPAK2.DEP

This file lists age-specific fractional deposition in Regions 1-9 of the HRTM for each of 35 particle sizes. This file is used to derive age-specific deposition fractions in each of the nine regions for an arbitrary particle size, for the purpose of calculating dose coefficients.

RISKCOEF.DEP

This file lists average deposition fractions in Regions 1-9 of the HRTM over each of four age ranges for each of 35 particle sizes. This file is used to derive age-group-specific deposition fractions in each of the nine regions for an arbitrary particle size, for the purpose of calculating risk coefficients.

Vapors.TXT, Ingest.TXT, and Inhale.TXT

The files Vapors.TXT, Ingest.TXT, and Inhale.TXT contain the names of specific chemical forms when considered for ingestion and inhalation intakes. For each radionuclide, DCFPAK2.NDX contains information indicating the treatment of vapors/gases forms, more than one chemical form for ingestion, and more than three chemical forms inhalation. These text files are accessed to indentify the chemical form in output tables.

APPLICATION OF DCFPAK 2.2

The DCFPAK2 software was designed for use on a personal computer with Windows operating system (Windows 98/Me/NT/2000/XP/Vista). DCFPAK 2.2 is installed in the default folder DCFPAK2 or a folder of choice, and its data files, the DCFPAK 2.2 library, are placed in the subfolder \DATA. An icon is also placed on the desktop. The software allows an interactive examination of DCFPAK 2.2 files for any of the exposure modes and radionuclides addressed in this package. A brief description of the data files in the library is given in the preceding section.

To access DCFPAK 2.2, click on its icon on the desktop. If the icon is not on the desktop, start Windows Explorer and click on the DCFPAK2 executable in its folder. This opens a periodic chart of the elements (Figure 2). Note that the last line of the display indicates that the function keys F1 through F4 have been defined to provide specific information regarding the radionuclides of the library and to display this document via the F4 key.

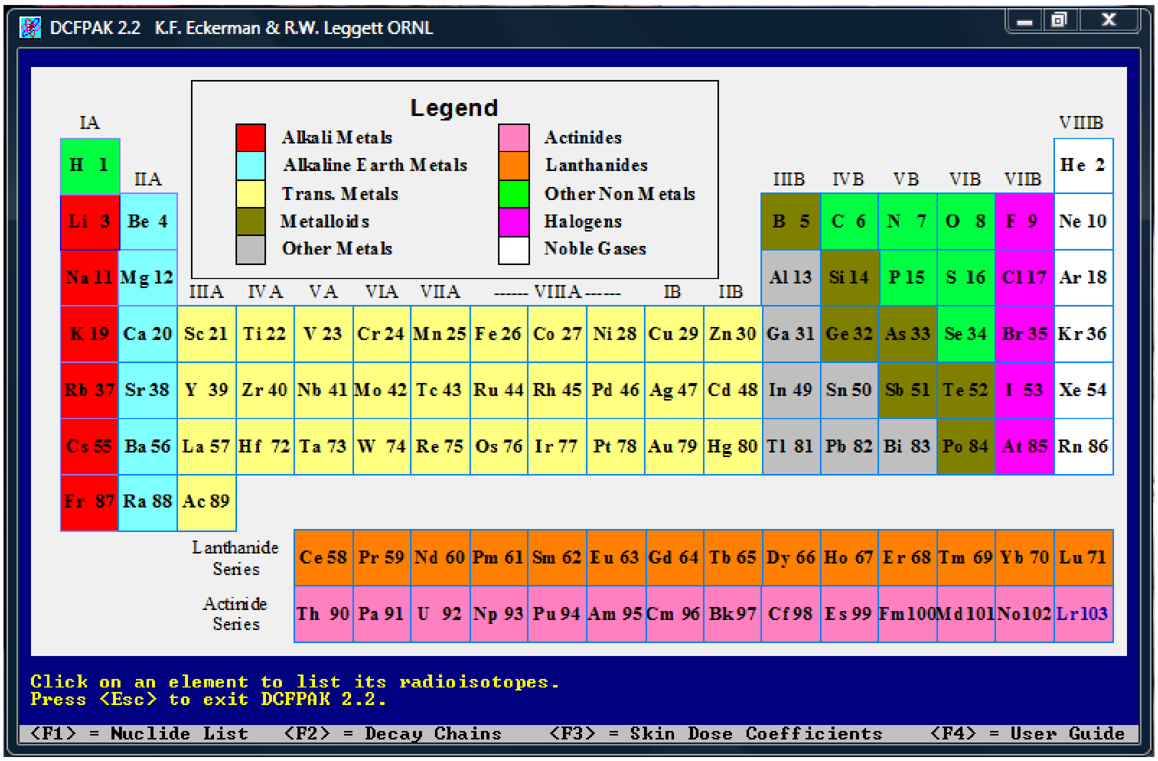
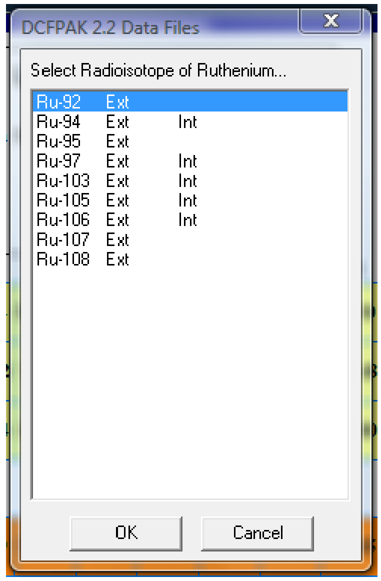
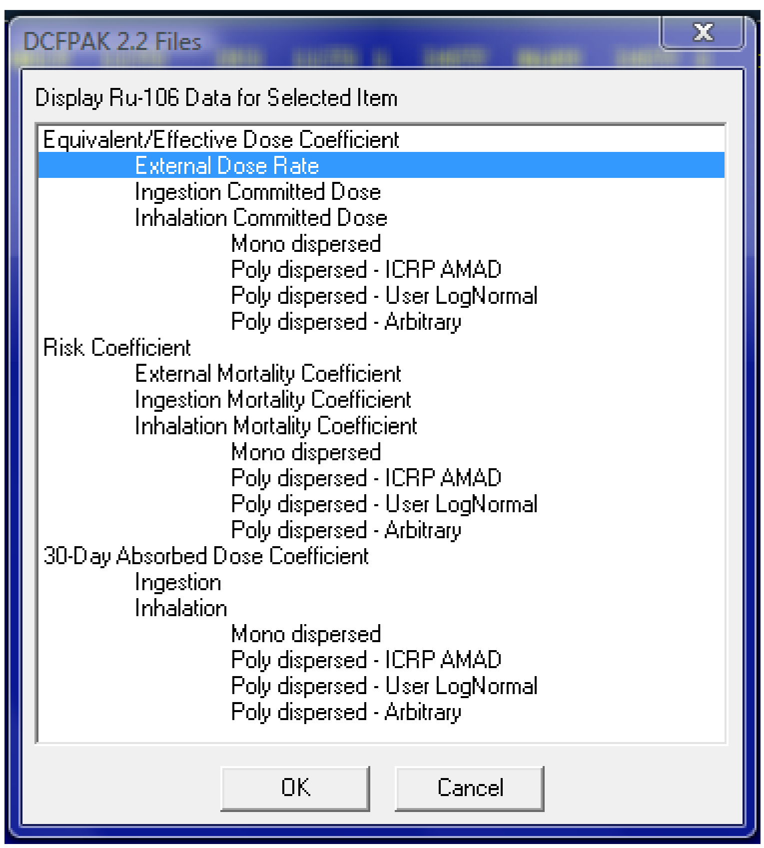


Figure 2. Periodic chart of the elements displayed when DCFPAK 2.2 is opened.

Suppose you want information on Ru-106. Click on Ru to list all isotopes of ruthenium addressed in DCFPAK 2.2 and general modes of exposure addressed for each isotope, i.e., external (Ext) or internal (Int) exposure:



Both external (Ext) and internal (Int) exposure modes are addressed for Ru-106 but only external exposure is addressed for Ru-95, for example. Click on Ru-106 to see a list of specific external and internal exposure pathways addressed. The following menu will be shown:



If you choose "Equivalent/Effective Dose Coefficient":

Click on "External Dose Rate" to see a table of organ-specific and effective dose rate coefficients for Ru-106 for the following external exposure modes: air submersion, water immersion, standing on a contaminated ground surface, and standing on soil contaminated to a specified depth. The external dose rate coefficients are for the parent radionuclide only, i.e., they do not include contributions to external dose from any radioactive progeny (in this case Rh-106), which must be viewed separately. As is true of any data displayed by the software, the information can be saved as a file in the default folder C:\DCFPAK2\OUTPUT or at user-assigned location. The user may keep or change the suggested name of the file.

Click on "Ingestion Committed Dose" to see age-specific committed equivalent and effective dose coefficients for ingested Ru-106. These coefficients are based on acute intake of the parent radionuclide Ru-106 only but include the contribution to dose from radioactive progeny (Rh-106) produced in the body. Committed dose refers to a 50-y period after intake by adults and to age 70 y after intake at a pre-adult age.

To generate a table of age-specific committed equivalent and effective dose coefficients for inhaled Ru-106 of a specified particle size, click on one of the four choices of particle size definitions under "Inhalation Committed Dose" and then follow instructions for defining the particle size distribution.

- If "Mono dispersed" is chosen, you will be asked to enter the monodispersed aerodynamic particle diameter in micrometers (μm).
- If "Poly dispersed – ICRP AMAD" is chosen, you will be asked to enter the AMAD in micrometers (μm). ICRP's default geometric standard deviation (GSD) for that AMAD is applied.
- If "Poly dispersed – User LogNormal" is chosen, you will be asked to enter both the AMAD and the GSD.
- If "Poly dispersed – Arbitrary" is chosen, you will be asked to select a file containing a histogram representation of the sizes of particles in the aerosol. This file has to be created earlier and saved in the sub folder INPUT with the file extension INP. Two example INP files are contained in the folder. The file specifies whether the particle sizes are in terms of aerodynamic diameter or physical diameter. If "physical diameter" is specified, then the bulk density (g/cm^3) and shape factor (arbitrary units) must be indicated. DCFPAK2 will convert the entries from physical diameter to aerodynamic diameter and normalize the histogram. An illustrative histogram defined in terms of aerodynamic diameters is shown below:

AERODYNAMIC DIAMETER
START INPUT

3.0	4.0	0.1
4.0	5.0	0.1
5.0	7.0	0.3
7.0	8.0	0.2
8.0	9.5	0.05

END INPUT

In this example, "AERODYNAMIC DIAMETER" specifies the measure of particle size and the histogram is entered between the delimiters "START INPUT" and "END INPUT". The first two entries in each row of numbers define a range of aerodynamic sizes and the third number is the relative number of particles with diameter in that range. DCFPAK2.2 normalizes the relative values in the third column so that their sum is 1.0. In this example, the sum of values in the third column is 0.1+0.1+0.3+0.2+0.05=0.75. Thus, the fraction 0.1/0.75 of particles have aerodynamic diameter in the range 3.0-4.0 µm, the fraction 0.1/0.75 of particles have aerodynamic diameter in the range 4.0-5.0 µm, the fraction 0.3/0.75 have aerodynamic diameter in the range 5.0-7.0 µm, and so forth.

A histogram in terms of physical diameters is illustrated below:

PHYSICAL DIAMETER
DENSITY 4.0
SHAPE FACTOR 1.5
START INPUT

0.5	1.0	0.1
1.0	2.0	0.1
2.0	3.0	0.2
3.0	6.0	0.3
6.0	8.0	0.1

END INPUT

In this example, "PHYSICAL DIAMETER" specifies the measure of particle size, the particle density is 4.0 g/cm^3, and the shape factor is 1.5. The histogram is entered between the delimiters "START INPUT" and "END INPUT". The sum of values in the third column is 0.1+0.1+0.2+0.3+0.1=0.8. Thus, the fraction 0.1/0.8 of particles have physical diameter in the range 0.5-1.0 µm, the fraction 0.1/0.8 of particles have physical diameter in the range 1.0-2.0 µm, the fraction 0.2/0.8 have physical diameter in the range 2.0-3.0 µm, and so forth.

If dose coefficients are available for inhalation of the radionuclide as a vapor (which is true in the case of Ru-106), those coefficients are also listed whenever coefficients for a selected particle size are listed. Dose coefficients for particles or vapors are based on acute intake of the parent radionuclide (Ru-106) only but include the contribution to dose from radioactive progeny (Rh-106) produced in the body.

Committed dose refers to a 50-y period after intake by adults and to age 70 y after intake at a pre-adult age.

If you choose "Risk Coefficient":

Click on "External Mortality Coefficient" to see a table of organ-specific and total mortality cancer risk coefficients for Ru-106 for the following external exposure modes: air submersion, standing on a contaminated ground surface, and standing on soil contaminated to an infinite depth. The risk coefficients are for the parent radionuclide (Ru-106) and do not include the contribution to cancer risk from radioactive progeny (Rh-106) formed in the environment.

Click on "Ingestion Mortality Coefficient" to see a table of organ-specific and total mortality cancer risk coefficients for ingestion of Ru-106 in food or drinking water.

To generate a table of risk coefficients for inhalation of Ru-106 of a specified particle size, click on one of the four choices of particle size definitions under "Inhalation Mortality Coefficient" and then follow instructions for defining the particle size distribution. Options for selecting or defining particle sizes are the same as those described above for committed equivalent/effective dose coefficients for inhaled radionuclides. If risk coefficients are available for inhalation of the radionuclide as a vapor (which is true for Ru-106), those coefficients are also listed whenever coefficients for a selected particle size are listed. Risk coefficients for particles or vapors are based on intake of the parent radionuclide (Ru-106) only but include the contribution to cancer risk from radioactive progeny (Rh-106) produced in the body.

If you choose "30-d Absorbed Dose Coefficient":

Click on "Ingestion" to see age-specific 30-d absorbed dose coefficients for ingested Ru-106. These coefficients are based on acute intake of the parent radionuclide (Ru-106) only but include the contribution to dose from radioactive progeny (Rh-106) produced in the body.

To generate a table of 30-d absorbed dose coefficients for inhalation of Ru-106 of a specified particle size, click on one of the four choices of particle size definitions under "Inhalation" and then follow instructions for defining the particle size distribution. Options for selecting or defining particle sizes are the same as those described above for committed equivalent/effective dose coefficients for inhaled radionuclides. If 30-d absorbed dose coefficients are available for inhalation of the radionuclide as a vapor, those coefficients are also listed whenever coefficients for a selected particle size are listed. Dose coefficients for particles or vapors are based on intake of the parent radionuclide only but include the contribution to dose from radioactive progeny (Rh-106) produced in the body.

F1 key: Listing of the radionuclides addressed in DCFPAK 2.2

While the periodic chart is displayed, pressing the F1 key will display a listing of the radionuclides in the DCFPAK 2.2 library. The nuclides are ordered by atomic number with their physical half-life, decay mode, and the energy per nuclear transformation (decay event) of emitted alpha particles, electrons, and photons. The daughter nuclei are identified with stable nuclei so indicated.

F2 key: Listing of the serial decay chains of radionuclides in DCFPAK 2.2

A listing of the serial decay chains of radionuclides in the DCFPAK 2.2 library can be displayed by pressing the F2 key. The fraction of the decays (so-called branching fractions) forming the daughter nuclei are listed with stable nuclei so indicated. The fraction of decays by spontaneous fission is shown as the branching fraction for the 'daughter' SF.

F3 key: Listing of skin dose rate coefficients for radionuclides in DCFPAK 2.2

A listing of the absorbed dose rate to the skin from beta particles and electrons emitted by the radionuclides in contact with the skin is displayed by pressing the F3 key. The greater of the endpoint energy of the beta spectra or the maximum energy of discrete electrons is also shown. The skin dose coefficients were averaged over the depth of 5 to 10 mg cm^{-2} using the parametric expression in Table 3 of Faw (1992).

F4 key: Display DCFPAK 2.2 user guide

This function key displays the DCFPAK 2.2 user guide – this document.

Appendix A. Description of DCFPAK2.NDX file

DCFPAK2.NDX is the master index file that serves as the portal of entry into the data files of the DCFPAK 2.2 library. The structure of this file is detailed in Table A-1. Each of the 1252 radionuclides of the library has a record in the index file which contains eleven fields that serve as pointers into the data files and three fields that indicate the number of chemical forms of the radionuclide for which dose or risk coefficients are tabulated. These fields guide the retrieval of information for the radionuclide of interest.

The data records of the index file are sorted by the nuclide field to enable use of a binary search procedure to locate the record for a radionuclide of interest. The numerical values of the pointer fields in the nuclide record correspond to (points to) the nuclide record in the various data files. For example, Pointer-3 (see Table A-1) contains the record number of the nuclide in the file of equivalent dose coefficients for ingestion intakes of the radionuclide (the DCF_INGS.DAT file). If Pointer-3 is zero then no ingestion coefficient is present for the radionuclide.

The pointer fields contain the locations of the first record for the nuclide in the targeted files. The number of records in the file for that nuclide is indicated by the number field for ingestion and inhalation. Dose and risk coefficients for external exposures are present for all radionuclides of the library. As an example, Number-1 is the number of chemical forms of the radionuclide for which dose and risk ingestion coefficients are present in targeted files (DCF_INGS.DAT. DCF_INGS.D30, and DCF_INGS.RBS). Normally this field has a value of 1 but for a limited number of nuclides additional chemical forms were considered in FGR 13. If Number-1 is zero then no ingestion coefficients for the nuclide are in the library and if nonzero then coefficients for this number of chemical forms are present. If Number-1 is greater than 1 then the file INGEST.TXT can be accessed to identify the chemical forms of the radionuclide in the output tables. The fields Number-2 and Number-3 provide the corresponding information for inhalation of particulate aerosols and vapor/gas forms, respectively. If Number-2 is zero then no dose or risk coefficients for inhalation are present for the radionuclide. In FGR 13 the three clearance types F, M, and S were routinely considered and thus for most radionuclides Number-2 has a value of three. The exception is radionuclides of mercury for which both organic and inorganic forms were considered. Thus the Number-2 field of the record of mercury isotopes for which inhalation coefficients were calculated contains a 6 and the file INHALE.TXT is access to identify the two chemical forms (two sets of the three absorption types) in output files. Number-3 field contains the number of vapor and gaseous forms of the radionuclide. If this field is nonzero that the file VAPORS.TXT is accessed to identify the chemical forms in the output files.

All the data files of the library are formatted direct access files. Each record contains a CR and LF such that the files can be viewed within an ASCII editor. The structure of the data files of the library is self-evident when examined within an editor.

Table A-1. Structure of Records in the DCFPAK2.NDX File		
Field	**Format[a)]**	**Description**
Record 1[b)]		
First	I4	Record number of first data record (2)
Last	I4	Record number of last data record (1253)
Data Records (First, ..., Last)[c)]		
Nuclide	A7	Name of nuclide (parent); e.g., Am-241, Tc-99m
Half-life	A8	Half-life of nuclide
Units	A2	Half-life units: us - microsecond, ms - millisecond, s – second, m – minute, d - day, and y – year
Pointer-1	I5	Location of nuclide in FGR12III_N.DAT files
Pointer-2	I6	Location of nuclide in EXTRISKS.RBS files
Pointer-3	I6	Location of nuclide in DCF_INGS.DAT file
Pointer-4	I6	Location of nuclide in DCF_INGS.RBS file
Pointer-5	I6	Location of nuclide in DCF_INGS.D30
Number-1	I2	Number of chemical forms of nuclide for ingestion
Pointer-6	I6	Location of nuclide in *.HDB files
Pointer-7	I6	Location of nuclide in *.RBS files
Pointer-8	I6	Location of nuclide in *.D30 files
Number-2	I2	Number of chemical forms of nuclide for inhalation
Pointer-9	I6	Location of nuclide if vapor/gas in DCFVAPOR.DAT
Pointer-10	I6	Location of nuclide if vapor/gas in DCFVAPOR.RBS
Pointer-11	I6	Location of nuclide if vapor/gas in DCFVAPOR.D30
Number-3	I2	Number of vapor/gas forms of nuclide

[a)]The format is expressed in FORTRAN notation, e.g., A8 denotes an alphanumeric field of length 8, and I6 is an integer field of length 6.
[b)]FORTRAN Format(2I4)
[c)]FORTRAN Format (A7,A8,A2,I5, 4I6, I2, 3I6,I2, 3I6, I2)

REFERENCES

Eckerman, K. F.; Endo, A. (2008). MIRD: Radionuclide data and decay schemes. The Society of Nuclear Medicine Reston VA.

Eckerman, K. F.; Leggett, R. W. (1996). DCFPAK: Dose Coefficient Data File Package for Sandia National Laboratory. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-13347; 1996.

Endo, A.; Yamaguchi, Y.; Eckerman, K. F. (2005a). Nuclear decay data for dosimetry calculation: Revised cata of ICRP Publication 38. Japan Atomic Energy Research Institute, JAERI 1347.

Endo, A. (2005b). Nuclear decay data for dosimetry calculation: Supplement to JAERI 1347. Japan Atomic Energy Research Institute, JAERI 1347S.

Endo, A.; Eckerman, K. F. (2007). Nuclear decay data for dosimetry calculations: Data for radionuclides with half-lives less than 10 minutes. Japan Atomic Energy Agency, JAEA-Data/Code 2007-021.

EPA (1988). Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Federal Guidance Report No. 11 (FGR11), EPA-520/1-88-020 (Oak Ridge National Laboratory, Oak Ridge, TN; U. S. Environmental Protection Agency, Washington, DC).

EPA (1993). External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report No. 12 (FGR12), EPA-402-R-93-081 (Oak Ridge National Laboratory, Oak Ridge, TN; U. S. Environmental Protection Agency, Washington, DC).

EPA (1999). Cancer Risks from Low-Level Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, EPA-402/R-99-001 (Oak Ridge National Laboratory, Oak Ridge, TN; U. S. Environmental Protection Agency, Washington, DC).

Faw, R. E. (1992). *Absorbed doses to skin from radionuclide sources on the body surface*. **Health Phys. 63**:443-448.

ICRP (1977). *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 26. **Ann. ICRP 1**.

ICRP (1979). *Limits for Intakes by Workers*, ICRP Publication 30, Part 1. **Ann. ICRP 2**(3/4).

ICRP (1980). *Limits for Intakes by Workers*, ICRP Publication 30, Part 2. **Ann. ICRP 4**(3/4), Oxford).

ICRP (1981). *Limits for Intakes by Workers*, ICRP Publication 30, Part 3. **Ann. ICRP 6**(2/3).

ICRP (1983). *Radionuclide Transformations: Energy and Intensity of Emissions*, ICRP Publication 38. **Ann. ICRP 11-13**.

ICRP (1988). *Limits for Intakes by Workers*, ICRP Publication 30, Part 4. **Ann. ICRP 19**(4).

ICRP (1989). *Age-Dependent Doses to Members of the Public from Intake of Radionuclides*, Part 1, ICRP Publication 56. **Ann. ICRP 20**(2).

ICRP (1991). *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60. **Ann. ICRP 21**(1-3).

ICRP (1993). *Age-Dependent Doses to Members of the Public from Intake of Radionuclides*, Part 2, ICRP Publication 67. **Ann. ICRP 23**(3/4).

ICRP (1994). *Human Respiratory Tract Model for Radiological Protection*, ICRP Publication 66. **Ann. ICRP 24**(1-3).

ICRP (1995a). *Age-Dependent Doses to Members of the Public from Intake of Radionuclides*, Part 3, ICRP Publication 69. **Ann. ICRP 25**(1).

ICRP (1995b). *Age-Dependent Doses to Members of the Public from Intake of Radionuclides*, Part 4, ICRP Publication 71. **Ann. ICRP 25**(3/4).

ICRP (1996). *Age-Dependent Doses to Members of the Public from Intake of Radionuclides*, Part 5. *Compilation of Ingestion and Inhalation Dose Coefficients*, ICRP Publication 72. **Ann ICRP 26**(1).

ICRP (2008). *Nuclear Decay Data for Dosimetric Calculations*. ICRP Publication 107. **Ann ICRP 38**(3).