ORNL-5692

ornl

OAK
RIDGE
NATIONAL
LABORATORY

UNION
CARBIDE

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DARTAB: A Program to Combine Airborne Radionuclide Environmental Exposure Data with Dosimetric and Health Effects Data to Generate Tabulations of Predicted Health Impacts

C. L. Begovich
K. F. Eckerman
E. C. Schlatter
S. Y. Ohr
R. O. Chester

ORNL-5692
Dist. Categories UC-11, 41

Contract No. W-7405-eng-26

Health and Safety Research Division

DARTAB: A PROGRAM TO COMBINE AIRBORNE RADIONUCLIDE ENVIRONMENTAL EXPOSURE DATA WITH DOSIMETRIC AND HEALTH EFFECTS DATA TO GENERATE TABULATIONS OF PREDICTED HEALTH IMPACTS

C. L. Begovich
K. F. Eckerman
E. C. Schlatter
S. Y. Ohr
R. O. Chester

Date Published: August 1981

Work performed under
Interagency Agreement No. IAG-EPA-78-D-X0394
for U. S. Environmental Protection Agency
Office of Radiation Programs
C. B. Nelson, Project Officer

NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

CONTENTS

	Page
LIST OF FIGURES	v
LIST OF TABLES	vii
LIST OF SYMBOLS	ix
CONTENTS OF MICROFICHE	xi
ABSTRACT	xiii
1. INTRODUCTION	1
2. DISCUSSION OF METHODOLOGY	3
2.1 Radionuclide Exposure Data	4
2.2 Dosimetric Data File	5
2.2.1 Dosimetric data	6
2.2.2 Health effects data	7
2.2.3 Risk equivalent factors	9
2.2.3.1 Cancer risk equivalent factor	9
2.2.3.2 Genetic risk equivalent factor	10
2.2.4 Years of life lost estimates	10
2.3 General Equations	11
2.3.1 Radiological dose quantities	11
2.3.2 Health effects estimates	14
2.3.3. Tabulations of DARTAB	17
2.4 Example Tables	17
2.4.1 Example summary tables	17
2.4.2 Example detailed tables	23
2.4.3 Example location tables	23
3. PROGRAM SPECIFICATIONS	33
3.1 Subroutine Descriptions	33
3.2 Common Regions	35
3.3 User Input for DARTAB	38
3.4 Input Required for Dose Rates, Health Risks, and Risk Equivalent Factors	42
3.5 Input Required for Exposures	46
ACKNOWLEDGEMENTS	48
REFERENCES	49

LIST OF FIGURES

Page

1. Assessment of radiological health impacts 2

LIST OF TABLES

		Page
1.	Possible table types output by DARTAB	18
2.	Organ dose/exposure summary	19
3.	Pathway dose/exposure summary	20
4.	Nuclide dose/exposure summary	21
5.	Risk/risk equivalent summary	22
6.	Pathway risk/risk equivalent summary	24
7.	Nuclide risk/risk equivalent summary	25
8.	Example table of individual dose rate	26
9.	Example table of mean individual risk equivalent rate	27
10.	Example table of individual genetic dose	28
11.	Example table of fatal cancer rate	29
12.	Example table of collective genetic effect	30
13.	Example location table	31
14.	Sample file	39
15.	Possible values of indicator variable	44

LIST OF SYMBOLS

Symbol	Units	Definition
$D_{ij}(k)$	mrad/yr	The weighted sum of the organ dose rates for exposure to or intake of the ith radionuclide in the jth chronic exposure or intake pathway.
$D_{il}(k)$	mrad/yr	The dose rate to the lth organ of an individual at location k from the annual exposure or intake rate of the ith radionuclide.
$D_{jl}(k)$	mrad/yr	The dose rate to the lth organ at location k from annual exposure or intake in the jth exposure or intake pathway.
$D_{l}(k)$	mrad/yr	The total dose rate to the lth organ of an individual at location k.
DF_{ijl}	mrad-yr/pCi-yr mrad-cc/pCi-yr mrad-cm^2/pCi-yr	The absorbed dose rate factor for the lth organ due to a unit chronic exposure or intake rate of the ith radionuclide in the jth exposure or intake pathway.
$E_{ij}(k)$	person-pCi/yr person-pCi/cc person-pCi/cm^2	Chronic exposure to or annual intake rate of the ith radionuclide in the jth exposure or intake mode at the kth spatial location in the environment.
F_{ijl}	mrem/pCi mrem-cc/pCi-yr mrem-cm^2/pCi-yr	Cancer mortality risk equivalent factor for the lth organ per unit exposure to or intake of the ith nuclide through the jth exposure or intake pathway.
GC	Effects-yr/mrad 10^6 births	The number of genetic effects per million births associated with a gonadal dose rate of 1 mrad/yr of low-LET radiation.
GF_{ij}	mrem/pCi mrem-cc/pCi-yr mrem-cm^2/pCi-yr	Genetic risk equivalent factor per unit exposure to or intake of the ith radionuclide through the jth exposure or intake pathway.

LIST OF SYMBOLS (continued)

Symbol	Units	Definition
GR_{ij}	$\frac{\text{Effects-yr}}{10^6 \text{ birth-pCi}}$ $\frac{\text{Effects-cc}}{10^6 \text{ birth-pCi}}$ $\frac{\text{Effects-cm}^2}{10^6 \text{ birth-pCi}}$	Genetic risk factor per unit chronic exposure to or intake of the ith radionuclide in the jth exposure or intake pathway. Separate factors are included for low- and high-LET radiations.
HE	Effects/yr	Health effects rate in the population.
K_j	Various	Reconciles any pathway specific units to those required by DARTAB coding. Usually $K_j = 1$, dimensionless.
P(k)	Persons	The population residing at the kth spatial location in the environment.
R(k)	Effects	Total risk (number of health effects) experienced by the exposed population at location k.
RD_i	Effects-yr/mrem 10^5 persons	Mortality risk factor for cancer of the ith organ per organ dose rate of 1 mrad/yr of low-LET radiation.
RF_{ijl}	Effects-yr/pCi-10^5 persons Effects-cc/pCi-10^5 persons Effects-cm^2/pCi-10^5 person	Mortality risk factor for cancer of the ith organ per unit chronic exposure to or intake rate of the ith nuclide in the jth exposure or intake pathway. Separate factors are included for low- and high-LET radiation.
$Y_l(k)$	yr	Average life lost per premature death in the population.
YL_{ijl}	yr^2/pCi-10^5 persons yr-cc/pCi-10^5 persons yr-cm^2/pCi-10^5 persons	Total life lost by the cohort for a unit exposure to or intake of the ith nuclide in the jth exposure or intake pathway due to cancers of the ith organ.

CONTENTS OF MICROFICHE

Sheet 1

Frames (inclusive)	Contents
B1-E1	Main Program
E1-I1	RDSTOR
I1-J1	FACOUT
J1-L1	PREPDR
L1-P1	PREPHR
P1-G2	DRTAB
G2-I2	CHLOC
I2-J2	MULT
J2-K2	RDORGF
K2-N2	LOCTAB
N2-H3	SUMMRY
H3-G4	SUMMR2
H4	Test Case Description
H4-N5	Dose Rate and Risk Conversion Factors
N5	Organ Dose Weighting Factors
N5-P18	Output Tables
N5-G6	Summary Tables
N5-C6	Organ Dose/Exposure
C6-D6	Risk/Risk Equivalent
D6-E6	Pathway Risk/Risk Equivalent
E6-G6	Nuclide Risk/Risk Equivalent
G5-P18	Detail Tables
G6-P18	Pathway Detail
G6-I9	Individual Dose Equivalent Rate
I9-D11	Individual Genetic Dose Equivalent
D11-C14	Mean Individual Dose Equivalent Rate
C14-J15	Mean Individual Genetic Dose Equivalent
J15-L18	Collective Dose Equivalent
L18-P18	Collective Genetic Dose Equivalent

Sheet 2

Frames (inclusive)	Contents
B1-P18	Detail Tables (continued)
B1-D2	Pathway Detail (continued)
B1-D2	Collective Genetic Dose Equivalent (continued)
D2-B16	Nuclide Detail
D2-G5	Individual Dose Equivalent Rate
G5-H6	Individual Genetic Dose Equivalent
H6-P9	Mean Individual Dose Equivalent Rate
P9-G11	Mean Individual Genetic Dose Equivalent
G12-J14	Collective Dose Equivalent
J15-B16	Collective Genetic Dose Equivalent

CONTENTS OF MICROFICHE (continued)

Sheet 2 (continued)

Frames (inclusive)	Contents
B16-P18	Cancer Detail
B16-P18	Individual Lifetime Risk

Sheet 3

Frames (inclusive)	Contents
B1-L11	Detail Tables (continued)
B1-L11	Cancer Detail (continued)
B1-D1	Individual Lifetime Risk (continued)
D1-I2	Individual Genetic Effects per Birth
I2-K6	Mean Individual Lifetime Risk
K6-B7	Mean Individual Genetic Effects per Birth
B7-D10	Fatal Cancer Rate
D10-J11	Collective Genetic Effect
J11-L11	Fatal Cancer Rate (Location Tables)
end	

1. INTRODUCTION

The DARTAB computer code was written to provide tabulations of predicted impacts of radioactive airborne effluents by combining information on environmental concentrations with dosimetric and health effects data. Radionuclide intake rates and dosimetric and health effects information are used to calculate health impacts. DARTAB is independent of both the environmental transport code used to derive estimates of environmental concentrations and the origin of the dosimetric and health effects data. Thus, DARTAB eliminates the need to write similar coding in every environmental transport code in order to calculate doses and health impacts. The DARTAB computer code was developed at Oak Ridge National Laboratory (ORNL) at the request of the U. S. Environmental Protection Agency (EPA) to be used by that agency as part of a methodology to evaluate health risks to man from atmospheric releases of radionuclides.

In the examples presented in this report, exposure data for various environmental media were derived from the atmospheric transport code AIRDOS-EPA (Moore et al., 1979) and the dosimetric and health effects data base was developed using the RADRISK computer code (Dunning, Leggett, and Yalcintas, 1980). The basic life-table methodology used to derive health effects data in RADRISK was developed by the Office of Radiation Programs of the U. S. Environmental Protection Agency. It should be noted that doses calculated by AIRDOS-EPA are auxiliary output and are not used in DARTAB. A simplified information flow chart for DARTAB and the other codes used in the examples presented in this report is shown in Fig. 1. The figure illustrates the flow of information in an environmental assessment of human health impact from an atmospheric release of radionuclides (source term).

For the purposes of discussion in this document an internally consistent set of units for all of the parameters and calculated quantities has been used. The units used in the RADRISK file and the AIRDOS-EPA output are not identical and are given in Sect. 3.4 of this document.

ORNL-DWG 86-10238

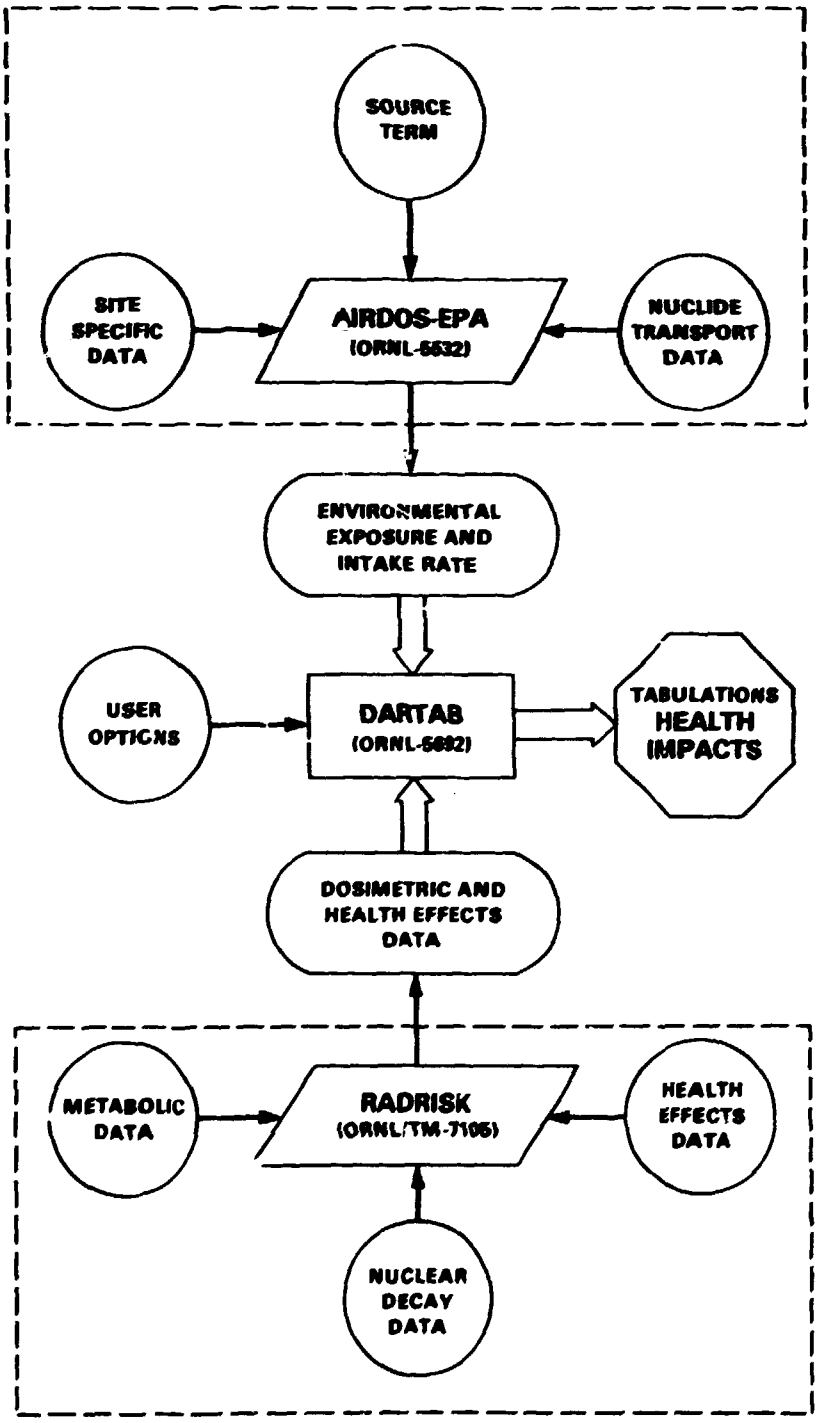

Fig. 1 Assessment of radiological health impacts.

2. DISCUSSION OF METHODOLOGY

Predictive assessments of health impact of radioactive material released to the environment involves the use of models and calculational techniques incorporated in computer codes. The resultant estimatations of dose and potential health effects are frequently tabulated in various formats to aid the users in understanding the interaction of various components of the assessment. Figure 1 illustrates the flow of information in such an assessment of the health impact of radioactive effluents released to the atmosphere. As illustrated, the AIRDOS-EPA code, an atmospheric and biotransport code, estimates environmental exposures and intake rates of the various radionuclides using site-specific data as well as information characterizing the released quantities (the source term). Due to the spatial dependence of atmospheric dispersion, the exposures to airborne and ground-plane depositions of radionuclides, and the intake rate of these radionuclides via ingestion of environmental media (vegetation, milk, meat, etc.) and inhalation, are estimated for specified location in the assessment region. These estimates of exposure or intake rates are then multiplied by information on organ dose commitment values per unit exposure or intake to estimate the radiological impact. These results can then be compared to regulatory standards or further calculation done to estimate the potential number of radiation-induced health effects in the exposed population.

In the approach to predictive assessments illustrated in Fig. 1, the RADRISK code is used to generate a data base of dosimetric and health effects information for various nuclides of potential interest in environmental assessments. This data base can then be used in environmental assessments, given appropriate computer software. It is the purpose of DARTAB to provide the software which accepts the environmental exposure to and intake rates of the released material and combine these quantities with the information in the dosimetric and health effects data base to yield tabulations of radiological health impacts.

It is important to note that the approach to estimation of radiological health impacts as outlined here and used in DARTAB is applicable only to low-level chronic exposure, since the health effects and dosimetric data were based on low-level chronic intakes. High-level exposures would lead to health effects estimates which are nonlinear with respect to exposure or intake. DARTAB and the dosimetric and health effects data base can not be used with either short-term or high-level intake of radionuclides.

2.1 Radionuclide Exposure Data

The annual collective exposure or intake rate from the ith radionuclide in the jth exposure pathway operating at location k in the environment for the radionuclides in the assessment are the basic input data to DARTAB. The radionuclide exposure data which are read by DARTAB are output from AIRDOS-EPA and are the product of the number of individuals residing at location k and the following quantities, air concentration, ground concentration, and intake rates for inhalation of air and ingestion of meat, milk, and vegetables for each radionuclide at each location, k, within the assessment area.

An exception is made for the short-lived daughters of Rn-222. For the Rn-222 progeny, the AIRDOS-EPA code calculates values of working level* instead of concentrations of individual radionuclides. The assumed fraction of equilibrium for the short-lived progeny used in AIRDOS-EPA calculations are also output for each location. The input to DARTAB for Rn-222 consists of the equilibrium fraction and the working level estimates rather than Rn-222 concentrations and intake rates. DARTAB calculates risk values, but not doses, from the working level estimates. Therefore, no high-LET inhalation, lung tissue doses or risks are calculated for Po-218, Pb-214, Bi-214, or Po-214. The Rn-222 air concentration, calculated from the working level and equilibrium fraction, is used to calculate doses and risks due to external exposure and inhalation of Rn-222.

---

*A working level (WL) is defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha particle energy.

2.2 Dosimetric Data File

DARTAB reads a dosimetric data file containing dosimetric and health effects data, in the form of factors, which can be applied to the exposure data supplied from environmental transport codes. The dosimetric data file is arranged by radionuclide. As such, the data for a given radionuclide correspond only to the dosimetric and health effects estimates associated with exposure to or intake of that radionuclide. In instances where radionuclides are members of decay chains (i.e., the nuclide decays to a nuclide which is also radioactive), no assumptions with regard to the relative exposure to or intake of the daughter have been included in the dosimetric data file. This rule has been followed rigorously in preparing the dosimetric data base. After intake into the body, however, daughter ingrowth is considered in situ in the development of the dosimetric data. The ingrowth of daughters and subsequent intake of or exposure to the daughters must be evaluated in the environmental transport codes supplying information to DARTAB. For example, in the decay of Cs-137 no photons are emitted, thus for exposure to deposited Cs-137, the organ dose rate factors are zero. The short-lived daughter product Ba-137 however does emit photon radiation and its ingrowth and decay results in organ doses from deposits of Cs-137 in the environment. Thus, to assess the radiological impact of Cs-137 releases, the transport code must include the ingrowth of Ba-137 in the environment and identify the exposures to this daughter in the input stream of DARTAB.

The dosimetric and health effects data files were developed using the RADRISK computer code of Dunning, Leggett, and Yalcintas (1980). The dose to various organs and risk associated with these organ doses are given for the radionuclides, exposure pathways, and organs of the body. The reader is referred to Dunning, Leggett, and Yalcintas (1980) for details. Briefly, the RADRISK code implements contemporary dosimetric methods to estimate doses to specified organs due to inhalation and ingestion of a radionuclide. These data, in the form of organ dose rates as a function of time during the chronic intake period, are processed through a life table methodology represented by the computer

code CAIRD, developed by the Office of Radiation Programs in the Environmental Protection Agency (Cook, 1978). The computer code RADRISK, utilizing CAIRD as a subroutine, performs calculations of the organ dose rate factors per unit intake rate as a function of time and also calculates the number of health effects in a hypothetical cohort of 100,000 persons continuously inhaling or ingesting the radionuclide.

2.2.1 Dosimetric data

The dosimetric information contained in the file includes consideration of internal exposure resulting from ingestion and inhalation of radionuclides, as well as external exposure from photons emitted by radionuclides exterior to the body, such as airborne and surface deposits of radioactive material. The dose values are the organ absorbed dose (rad), not dose equivalent (rem). In the case of internal emitters, the absorbed dose values are presented for both low- and high-LET (linear energy transfer) radiation associated with the decay of the nuclide. The LET classification considers alpha particles and the resultant recoiling nuclei to be high-LET radiation. Beta particles and gamma rays are classified as low-LET radiation. It is not necessary to consider a high-LET dose component for external irradiation of the body because such radiation cannot penetrate the outer skin layer. Skin doses from beta particles are not calculated. The DARTAB code permits the user to assign a radiation quality factor for low- and high-LET radiations for each organ or tissue such that the absorbed dose values for these two radiations can be combined into the dose equivalent.

For each exposure mode, dosimetric data are presented for 20 to 30 organs and tissues of the body. Various physicochemical forms for the nuclide may be needed in an assessment, and information for these forms has been included in the dosimetric data base. For example, dosimetric data for aerosols of various particle sizes expressed as activity median aerodynamic diameter (AMAD) and lung clearance classes are included in the data base. In the case of ingestion, the data are classified in terms of the GI-tract absorption factors (f_1 value) for potential physicochemical forms of the nuclide.

Because of the retention of inhaled and ingested radionuclides within the body, the organ dose rates under a constant intake rate increase with time. Organ-absorbed dose rates for both low- and high-LET radiations per unit intake rate as a function of time are contained in the file. The units of these factors are mrad/year per pCi/year – inhaled or ingested. Dose commitment values per unit intake are tabulated using the fact that the dose rate after 70 (or 50) years of uniform chronic intake is numerically equal to the 70 (or 50) year dose commitment for a unit intake. The dose commitment is the total dose over a future period associated with an intake.

Dose factors are also included in the data base for gonads. These factors correspond to the absorbed doses for the first 30 years of life of the exposed cohort which is assumed to be all simultaneously live-born and experiencing a unit intake rate throughout their lifetime (see Sect. 2.2.2). Thus, the calculation of genetic effects in offspring of the hypothetical cohort is based on the total dose experienced over the first 30 years of life. In actual populations, there will be a distribution of ages for the reproduction period. However, the use of a single age for this consideration is generally employed in assessment calculations (NAS, 1972) as has been done here.

The external exposure dosimetric data were taken from the work of Kocher (1979). Kocher has tabulated factors relating organ-absorbed dose rates to the airborne concentration and surface concentrations for various radionuclides. The units of these factors are mrad/year per pCi/cc, in the case of airborne activity, and mrad/year per pCi/cm^2, in the instance of ground concentration.

2.2.2 Health effects data

Health effects data were developed for each radionuclide-exposure pathway assuming a unit exposure rate. The health effects factors are evaluated as the number of incremental deaths within a cohort of 100,000 persons all simultaneously live-born and all experiencing a unit exposure or intake rate throughout the individual's lifetime. The results are expressed in terms of effects/10^5 per pCi/yr inhaled or

ingested, or effects/10^5 per pCi/cc or pCi/cm^2 for exposures to airborne or deposited activity. For the details of the calculation of health effects, the reader is referred to the document of Dunning, Leggett, and Yalcintas (1980) or the EPA report on CAIRD (Cook, 1978). Briefly, the organ dose rates at various times (annual doses) are used to estimate an annual incremental risk from radiation-induced cancer using radiation risk factors provided by the EPA. (These risk factors are based on an average of absolute and relative risks from the BEIR report [NAS 1972].) An important feature of the CAIRD code used in developing these estimates is that it employs actuarial life tables to allow for computing risks of death. A life table is essentially a tabulation of age-specific mortality rates for all causes of death in a given population. The calculation of the number of radiation-induced health effects basically consists of moving the cohort of 100,000 newborns throughout their life where at each age they experience a risk of death as indicated by the life table plus an incremental risk due to the radiation exposure or intake. The number of individuals estimated to die as a result of radiation-induced cancer is noted. Health effects are estimated for various radiogenic cancers (tabulated below) and genetic effects.

Cancer site/type

Stomach wall	Red marrow (leukemia)
Small intestine wall	Endosteal cells (bone)
Upper large intestine wall	Spleen
Lower large intestine wall	Testes
Bladder wall	Thymus
Kidneys	Thyroid
Liver	Uterus
Ovaries	Breast
Pancreas	Pulmonary (lung)

All health effects from internal emitters are given for both low- and high-LET radiations. The health effects are in units of number of effects in the cohort of size 100,000 per unit chronic exposure rate. Thus, the mortality risk RF_{ijl} for inhalation and ingestion is the

number of effects per 10^5 persons for a per capita intake rate of 1 pCi/yr. In the case of external irradiation, the exposure unit is pCi/cc or pCi/cm^2 for airborne and surface deposits, respectively.

2.2.3 Risk equivalent factors

Risk equivalent factors for a particular health effect are developed as the ratio of the number of health effects of a particular type in the cohort per unit exposure rate to the nuclide under consideration to those for a hypothetical low-LET radiation dose rate of 1 mrad per year. A low-LET dose rate of 1 mrad/yr is considered to have a risk equivalent rate value of 1 mrem/yr. Hence, the units of a risk equivalent factor are mrem/unit exposure (or intake). These factors are developed for both fatal cancers and genetic effects.

2.2.3.1 Cancer risk equivalent factor. If RF_{ijl} denotes the mortality risk factor from cancer of the lth organ per unit exposure to or intake rate of the ith nuclide through the jth exposure or intake mode for high- and low-LET radiation, then the risk equivalent factor for the lth organ is defined

$$F_{ijl} = \frac{RF_{ijl}^{\text{low-LET}} + RF_{ijl}^{\text{high-LET}}}{RD_l}, \qquad (1)$$

where RD_l denotes the cohort risk to the lth organ for a low-LET dose rate of 1 mrem/yr. The whole body risk equivalent factor for nuclide i and exposure pathway j is defined

$$F_{ij} = \frac{\sum_l RF_{ijl}^{\text{low-LET}} + RF_{ijl}^{\text{high-LET}}}{\sum_l RD_l}, \qquad (2)$$

where the risks are summed over all organs.

2.2.3.2 Genetic risk equivalent factor. A genetic risk equivalent factor, GF_{ij}, can be defined as

$$GF_{ij} = \frac{GR_{ij}^{low\text{-}LET} + GR_{ij}^{high\text{-}LET}}{GD}, \quad (3)$$

where

GR_{ij} is the number of genetic effects per million births to the population exposed to the radiation of the ith nuclide via the jth exposure pathway per unit exposure or intake rate,

GD is the number of genetic effects per million births associated with a low-LET radiation dose rate of 1 mrad/yr.

The factors $GR_{ij}^{low\text{-}LET}$ and $GR_{ij}^{high\text{-}LET}$ are the product of the gonadal dose factors for the ith nuclide in the jth pathway and the generic risk factors for low- and high-LET radiation (effects per 10^6 births per unit absorbed dose). Genetic risk factors of 300 and 30,000 effects per 10^6 births per rad for low- and high-LET radiations were supplied by EPA to be used in the calculations.

2.2.4 Years of life lost estimates

As an additional measure of impact of the intake or exposure to the radionuclides, RADRISK estimates the years of life lost in the cohort for unit exposure to or intake rate of the radionuclides. The total years of life lost for nuclide i in pathway j and for cancer l is denoted as YL_{ijl} and has units of years per 10^5 persons per pCi/yr inhaled or ingested activity or pCi/cm^3, pCi/cm^2 for external exposures. These values are simply the difference between the years of life lived by the 10^5 newborn cohort with and without the incremental risk from radiation.

2.3 General Equations

2.3.1 Radiological dose quantities

The annual dose committed to an individual at location k for the lth organ, ith nuclide, and jth exposure pathway is given by

$$D_{ijl}(k) = \frac{K_j E_{ij}(k) \cdot DF_{ijl}}{P(k)} , \qquad (4)$$

where K_j embodies any numerical factors introduced by the units of E_{ij} and DF_{ijl} and where $E_{ij}(k)$ is the exposure to the ith radionuclide in the jth pathway, DF_{ijl} is the dose rate factor for the ith radionuclide, the jth pathway and the lth organ, and P(k) is the exposed population at location k. Note that all E_{ij} and DF_{ijl} for various nuclides (index i) and organs (index l) have consistent units.

DARTAB performs three calculations and tabulations of dose rate and dose: 1) dose rate to an individual at a selected location, 2) dose rate to a mean or average individual, and 3) collective population dose rate. For example,

1. Selected individual dose rate, $D_{ijl}(k)$,(mrad/yr)

   a) Contributions via the ingestion and inhalation exposure pathways

$$= \frac{\underset{\text{(intake rate, person-pCi/yr)}}{E_{ij}(k)} \times \underset{\text{[dose rate, (mrad/yr)/(pCi/yr)]}}{DF_{ijl}}}{\underset{\text{(exposed population at the user selected location)}}{P(k)}} \times K_j \text{ (1, dimensionless)}$$

b) Air immersion pathway

$$= \frac{\underset{\text{(exposure rate, person-pCi/cm}^3\text{)}}{E_{ij}(k)} \times \underset{\text{[dose rate factor, (mrad/yr)/(pCi/cm}^3\text{)]}}{DF_{ijl}}}{\underset{\text{(exposed population at the user selected location)}}{P(k)}} \times \underset{\text{(1, dimensionless)}}{K_j}$$

c) Ground surface exposure pathway

$$= \frac{\underset{\text{(exposure rate, person-pCi/cm}^2\text{)}}{E_{ij}(k)} \times \underset{\text{[dose rate factor, (mrad/yr)/(pCi/cm}^2\text{)]}}{DF_{ijl}}}{\underset{\text{(exposed population at the user selected location)}}{P(k)}} \times \underset{\text{(1, dimensionless)}}{K_j}$$

2. Mean individual (over all locations) dose rate, D_{ijl}, (mrad/yr) is the weighted sum of individual dose rates as calculated in 1

$$D_{ijl} = \frac{\sum_k P(k) \times D_{ijl}(k)}{\sum_k P(k)}$$

3. Collective dose rate for the exposed population $\sum_k D_{ijl}$ (person-rad/yr)

(mean individual dose rate, mrad/yr) × (exposed population) × ($K_j = 10^{-3}$ rad/mrad)

The doses can be summed directly over pathways:

$$D_{il}(k) = \sum_{j} D_{ijl}(k) \ , \tag{5}$$

or nuclides:

$$D_{jl}(k) = \sum_{i} D_{ijl}(k) \ . \tag{6}$$

The total dose to the lth organ at location k, $D_l(k)$, is then

$$D_l(k) = \sum_{j} \sum_{i} D_{ijl}(k) \ . \tag{7}$$

The dose equivalent (mrem), H_l, for the lth organ is given as

$$H_l(k) = QF(\text{low-LET}) \times D_l(k, \text{ low-LET}) + QF(\text{high-LET}) \times D_l(k, \text{ high-LET}),$$

where QF denotes the relative biological effect factor. The factor is defined for each organ or health effect.

To combine doses to different organs, a weighted sum is used:

$$D_{ij}(k) = \sum_{l} W_l D_{ijl}(k) \ , \tag{8}$$

where W_l are weighting factors for the various organ doses supplied by the user where

$$\sum_{l} W_l = 1 \ .$$

Weighting factors for the various organs have been supplied by EPA for input into DARTAB. Note a similar approach to adding organ doses has

been proposed by the International Commission on Radiological Protection (ICRP, 1979).

2.3.2 Health effects estimates

The health risk and risk equivalent can be similarly computed. The health risk or individual risk of premature death to an individual at location k for the lth cancer, ith radionuclide, and jth exposure pathway is given by:

$$R_{ijl}(k) = 10^{-5} \times K_j E_{ij}(k) RF_{ijl}/P(k) \ , \tag{9}$$

where K_j again serves to reconcile the units of $E_{ij}(k)$ and RF_{ijl}. The total individual risk represented by the exposures and intakes of all radionuclides through all pathways is given as:

$$R(k) = 10^{-5} \sum_j K_j \sum_i E_{ij}(k) \sum_l RF_{ijl}/P(k) \ , \tag{10}$$

and the health risk can be summed over pathways, radionuclides, or cancers. The mean or average individual risk is estimated in a similar way.

The collective risk is expressed as the health effects rate. For example, the total equilibrium fatal cancer rate in the exposed population is:

$$HE = \frac{10^{-5}}{T_e} \sum_j K_j \cdot \sum_k \sum_i E_{ij}(k) \sum_l RF_{ijl} \ , \tag{11}$$

where T_e is the mean individual lifetime (70.7 years).

In DARTAB, life loss (years) per premature death is calculated

$$Y_l(k) = \frac{\sum_j K_j \sum_i E_{ij}(k) YL_{ijl}}{\sum_j K_j \sum_i E_{ij}(k) RF_{ijl}} \ , \tag{12}$$

where

$Y_l(k)$ = average life lost (years) per premature death from cancer l at location k,

YL_{ijl} = total life lost (years) for unit exposure to nuclide i, pathway j, and cancer l,

$E_{ij}(k)$ = is the exposure to or intake rate of the ith radionuclide through the jth exposure or intake model at location k in the environment,

RF_{ijl} = the mortality risk factor per unit exposure or intake rate of the ith radionuclide in the jth exposure or intake mode for the lth cancer site.

The factor K_j converts any pathway specific units to the required units. Note then that the numerator is just the total years of life lost by those experiencing a cancer of the lth site, while the denominator is the total number of deaths due to radiation induced cancers of the lth site.

DARTAB performs three calculations and tabulations of life loss per premature death 1) life loss per premature death for an individual at a selected location and 2) life loss per premature death for a mean or average individual. For example,

1. Selected individual life loss/premature death, $Y_t(k)$ (yr/premature death)

   a) Contributions via the ingestion and inhalation exposure pathways

$$= \frac{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times YL_{ijl}}{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times RF_{ijl}}$$

$$(1, \text{dimensionless}) \times (\text{intake, person } \frac{pCi}{yr}) \times \left[\frac{\text{life loss}/10^5 \text{ persons}}{\text{unit intake}}, \frac{yr}{(\frac{pCi}{yr})}\right]$$

$$(\text{intake, person } \frac{pCi}{yr}) \times \left[\frac{\text{cancer mortality risk factor}}{\text{unit intake}}, \frac{(\frac{\text{deaths}}{10^5 \text{ persons}})}{(\frac{pCi}{yr})}\right]$$

b) contributions via the air immersion pathway

$$= \frac{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times YL_{ijl}}{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times RF_{ijl}}$$

$$= \frac{(1\text{ dimensionless}) \times \left(\text{exposure, person } \frac{pCi}{cm^3}\right) \times \left[\frac{\text{life loss}/10^5\text{ persons}}{\text{unit exposure}}, \frac{yr}{\left(\frac{pCi}{cm^3}\right)}\right]}{\left(\text{exposure, person } \frac{pCi}{cm^3}\right) \times \left[\frac{\text{cancer mortality risk factor}}{\text{unit exposure}}, \frac{\left(\frac{\text{deaths}}{10^5\text{ persons}}\right)}{\left(\frac{pCi}{cm^3}\right)}\right]}$$

c. Contributions via the ground surface exposure pathway

$$= \frac{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times YL_{ijl}}{\sum_{\substack{\text{nuclides}\\\text{pathways}}} K_j \times E_{ij}(k) \times RF_{ijl}}$$

$$= \frac{(1\text{ dimensionless}) \times \left(\text{exposure, person } \frac{pCi}{cm^2}\right) \times \left[\frac{\text{life loss}/10^5\text{ persons}}{\text{unit exposure}}, \frac{yr}{\left(\frac{pCi}{cm^2}\right)}\right]}{\left(\text{exposure, person } \frac{pCi}{cm^2}\right) \times \left[\frac{\text{cancer mortality risk factor}}{\text{unit exposure}}, \frac{\left(\frac{\text{deaths}}{10^5\text{ persons}}\right)}{\left(\frac{pCi}{cm^2}\right)}\right]}$$

2. Mean individual life loss/premature death Ye(k) is the $\sum_{\text{locations}}^{\text{all}}$ of individual life loss as calculated in 1.

2.3.3 Tabulations of DARTAB

From the above equations it can be seen that tabulations of the numerical data (dose quantities, health risks, or risk equivalents) are provided in such a way that the contribution of the various radionuclides (index i), pathways (index j), and body organs or cancers (index l) to the total impacts, as measured by individual, mean individual, and collective dose or health effects, can be examined. The DARTAB code provides the user with extensive options with regard to the form and structure of these tables. Three types of tables can be obtained. First, summary tables give dose and health effects estimates for organ or cancer, radionuclide, and pathway.

The second type of table is a more detailed tabulation where the dose and health effects are estimated for two of the three quantities: radionuclides, pathways, and organs or cancers. The types of tables that can be printed are summarized in Table 1.

The final type of table summarizes the data for all locations. A particular nuclide, pathway, and organ or cancer must be specified.

Examples of the tables are given in the next section. A complete set is included in the microfiche inside the back cover. A description of how to select the tables to be printed is given in Sect. 3.3.

2.4 Example Tables

2.4.1 Example summary tables

Examples of the summary tables for dose quantities are given in Tables 2-4. The microfiche inside the back cover includes a complete tabulation of all tables generated by DARTAB as well as the input parameter values for the DARTAB run. Table 2 summarizes the total dose to each organ, summed over pathways and nuclides. The radon daughter working level exposures are listed, and the 30-year gonadal doses are tabulated. Each of the tables is given for the selected individual, the mean individual, and the collective population. Tables 3 and 4 are analogous to Table 2 except that the weighted-doses are summed by pathways (Table 3) or nuclides (Table 4). Table 5 gives lifetime fatal

Table 1. Possible table types output by DARTAB

Table type	Variable		Constant
	Column label	Row label	
a	Organs or cancers	Radionuclides	Individual pathways
b	Organs or cancers	Radionuclides	External and internal
c	Organs or cancers	Radionuclides	All pathways
d	Radionuclides	Pathways	Organs or cancers
e	Organs or cancers	Pathways	Radionuclides
f	Radionuclides	Pathways	Summed over organs or cancers
g	Organs or cancers	Pathways	Summed over radionuclides
h	Compass direction	Distance meters	User specified

Table 2. Organ dose/exposure summary (example case)

EXAMPLE CASE

ORGAN DOSE/EXPOSURE SUMMARY

*** SELECTED INDIVIDUAL *** (located 1500 meters ENE of source)

DOSE RATES:

ORGANS:	R MAR ULI WALL	ENDOST SI WALL	*PUL* OVARIES	MUSCLE TESTES	LIVER SPLEEN	S WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS MT.SUM	BL WALL
LOW LET (MRAD/Y)	4.83E-03	5.32E-03	7.63E-03	4.47E-03	3.89E-03	3.77E-03	4.25E-03	3.36E-03	3.79E-03	3.96E-03
	4.32E-03	3.31E-03	3.20E-03	3.87E-03	4.02E-03	3.16E-03	3.98E-03	4.30E-03	5.26E-03	
HIGH LET (MRAD/Y)	9.30E-03	7.40E-02	.434	4.70E-03	1.48E-02	1.57E-05	4.70E-03	6.25E-04	8.36E-12	2.35E-01
	2.07E-04	3.51E-05	4.70E-03	4.70E-03	.145	4.70E-03	4.70E-03	4.70E-03	.134	
DOSE EQUIVALENT (MREM/Y)	.192	1.09	8.68	9.08E-02	.296	4.08E-03	9.82E-02	1.59E-02	1.65	5.10E-02
	8.46E-03	4.71E-03	9.72E-02	9.78E-02	2.90	9.71E-02	9.79E-02	9.83E-02	2.60	

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 7.22E-08

GONADAL DOSES:

GONADS:	TESTES	OVARIES	AVERAGE
LOW LET (MRAD)	.114	9.71E-02	.107
HIGH LET (MRAD)	.140	.140	.140
DOSE EQUIVALENT (MREM)	2.92	2.90	2.91

Weights supplied by user.
Contributions to these sums by pathway and nuclide are given in Tables 3 and 4.

*** MEAN INDIVIDUAL *** (collective dose rate or dose ÷ user specified total population)

DOSE RATE:

ORGANS:	R MAR ULI WALL	ENDOST SI WALL	*PUL* OVARIES	MUSCLE TESTES	LIVER SPLEEN	S WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS MT.SUM	BL WALL
LOW LET (MRAD/Y)	1.25E-04	1.42E-04	1.73E-04	1.13E-04	9.80E-05	9.51E-05	1.08E-04	9.95E-05	9.45E-05	1.00E-04
	1.12E-04	8.91E-05	8.23E-05	9.67E-05	1.01E-04	8.00E-05	1.00E-04	1.09E-04	1.28E-04	
HIGH LET (MRAD/Y)	6.46E-04	1.92E-03	8.56E-03	5.40E-04	1.66E-03	4.16E-06	5.40E-04	1.67E-04	9.58E-03	2.69E-04
	5.56E-05	9.35E-06	5.40E-04	5.40E-04	1.65E-02	5.40E-04	5.40E-01	5.40E-04	3.22E-03	
DOSE EQUIVALENT (MREM/Y)	1.30E-02	3.86E-02	.171	1.09E-02	3.33E-02	1.78E-04	1.09E-02	3.44E-03	.192	5.48E-03
	1.22E-03	2.76E-04	1.05E-02	1.09E-02	.331	1.09E-02	1.09E-02	1.09E-02	6.05E-02	

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 2.02E-09

GONADAL DOSES:

GONADS:	TESTES	OVARIES	AVERAGE
LOW LET (MRAD)	2.90E-03	2.46E-03	2.68E-03
HIGH LET (MRAD)	1.61E-02	1.61E-02	1.51E-02
DOSE EQUIVALENT (MREM)	.324	.324	.324

*** COLLECTIVE POPULATION ***

DOSE RATE:

ORGANS:	R MAR ULI WALL	ENDOST SI WALL	*PUL* OVARIES	MUSCLE TESTES	LIVER SPLEEN	S WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS MT.SUM	BL WALL
LOW LET (PERSON RAD/Y)	.406	.461	.562	.366	.318	.309	.350	.323	.307	.325
	.365	.289	.267	.314	.329	.260	.325	.364	.416	
HIGH LET (PERSON RAD/Y)	2.10	6.24	27.8	1.75	5.39	1.35E-02	1.75	.543	31.1	.873
	.180	3.04E-02	1.75	1.75	53.7	1.75	1.75	1.75	10.5	
DOSE EQ. (PERSON REM/Y)	42.3	125.	556.	35.4	108.	.579	35.4	11.2	622.	17.8
	3.96	.896	35.3	35.3	1.07E+03	35.3	35.3	35.4	210.	

RADON DAUGHTER EXPOSURE.
(PERSON WORKING LEVEL) 6.56E-03

GONADAL DOSES:

GONADS:	TESTES	OVARIES	AVERAGE
LOW LET (PERSON RAD)	9.40	7.99	8.69
HIGH LET (PERSON RAD)	52.2	52.2	52.2
DOSE EQ. (PERSON REM)	1.05E+03	1.05E+03	1.05E+03

Table 3. Pathway dose/exposure summary (example case)

EXAMPLE CASE

PATHWAY DOSE/EXPOSURE SUMMARY

*** SELECTED INDIVIDUAL ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (MRAD/Y)	1.97E-06	1.00E-03	2.12E-07	4.26E-03	1.00E-03	4.26E-03	5.26E-03
HIGH LET (MRAD/Y)	5.91E-04	.133	.0	.0	.134	.0	.134
DOSE EQUIVALENT (MREM/Y)	1.18E-02	2.67	2.12E-07	4.26E-03	2.68	4.26E-03	2.68

Contributions to this dose rate by organ and nuclide are given in Table 8.

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 7.22E-08

AVERAGE GONADAL DOSES:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (MRAD)	1.66E-05	5.78E-05	5.22E-06	.107	7.44E-05	.107	.107
HIGH LET (MRAD)	1.36E-02	.126	.0	.0	.140	.0	.140
DOSE EQUIVALENT (MREM)	.271	2.53	5.22E-06	.107	2.80	.107	2.91

Contributions to these sums by organ and nuclide are given in Tables 2 and 4.

*** MEAN INDIVIDUAL ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (MRAD/Y)	1.97E-06	1.96E-05	4.44E-09	1.07E-04	2.16E-05	1.07E-04	1.28E-04
HIGH LET (MRAD/Y)	5.91E-04	2.63E-03	.0	.0	3.22E-03	.0	3.22E-03
DOSE EQUIVALENT (MREM/Y)	1.18E-02	5.27E-02	4.44E-09	1.07E-04	6.45E-02	1.07E-04	6.46E-02

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 2.02E-09

AVERAGE GONADAL DOSES:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (MRAD)	1.66E-05	1.09E-06	1.09E-07	2.66E-03	1.77E-05	2.66E-03	2.68E-03
HIGH LET (MRAD)	1.36E-02	2.52E-03	.0	.0	1.61E-02	.0	1.61E-02
DOSE EQUIVALENT (MREM)	.271	5.04E-02	1.09E-07	2.66E-03	.322	2.66E-03	.324

*** COLLECTIVE POPULATION ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (PERSON RAD/Y)	6.39E-03	6.37E-02	1.44E-05	.346	7.01E-02	.346	.416
HIGH LET (PERSON RAD/Y)	1.92	8.54	.0	.0	10.5	.0	10.5
DOSE EQ. (PERSON REM/Y)	38.3	171.	1.44E-05	.346	209.	.346	210.

RADON DAUGHTER EXPOSURE:
(PERSON WORKING LEVEL) 6.56E-03

AVERAGE GONADAL DOSES:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (PERSON RAD)	5.40E-02	3.53E-03	3.54E-04	8.64	5.75E-02	8.64	8.69
HIGH LET (PERSON RAD)	44.0	8.17	.0	.0	52.2	.0	52.2
DOSE EQ. (PERSON REM)	880.	163.	3.54E-04	8.64	1.04E+03	8.64	1.05E+03

Table 4. Nuclide dose/exposure summary (example case)

EXAMPLE CASE

NUCLIDE DOSE/EXPOSURE SUMMARY

*** SELECTED INDIVIDUAL ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (MRAD/Y)	7.32E-04	5.41E-05	1.63E-05	1.60E-05	1.47E-04	1.23E-14	6.38E-14	3.88E-07	2.03E-04	1.79E-05
	1.83E-03	1.08E-05	1.92E-03	1.15E-07	2.02E-05	1.49E-17	3.01E-04	5.26E-03		
HIGH LET (MRAD/Y)	1.88E-03	.0	1.98E-03	2.93E-03	2.14E-04	.0	.0	.124	2.12E-03	1.70E-05
	2.15E-07	5.88E-04	.0	1.59E-06	1.36E-08	1.04E-19	2.67E-14	.130		
DOSE EQUIVALENT (MREM/Y)	3.79E-02	5.41E-05	3.97E-02	5.86E-02	4.43E-03	1.23E-14	6.38E-14	2.48	4.27E-02	3.58E-04
	1.83E-03	1.18E-02	1.92E-03	3.18E-05	2.05E-05	1.70E-17	3.01E-04	2.48		

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 7.22E-08

Contributions to these sums by organ and pathway are given in Tables 2 and 3.

AVERAGE GONADAL DOSES:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (MRAD)	2.75E-05	8.20E-04	1.04E-04	5.80E-05	4.10E-03	3.22E-13	1.59E-12	9.07E-06	3.46E-05	2.92E-05
	4.55E-02	1.48E-04	4.69E-02	6.92E-07	5.72E-04	4.26E-16	8.23E-03	.107		
HIGH LET (MRAD)	2.62E-05	.0	2.72E-06	2.01E-04	2.49E-04	.0	.0	.139	1.85E-04	1.20E-04
	1.91E-07	4.36E-04	.0	.0	1.41E-07	5.03E-19	1.05E-13	.140		
DOSE EQUIVALENT (MREM)	7.59E-05	8.20E-04	2.38E-04	4.08E-03	9.08E-03	3.22E-13	1.59E-12	2.78	3.74E-03	2.42E-03
	4.55E-02	8.88E-03	4.69E-02	6.92E-07	5.75E-04	4.36E-16	8.23E-03	2.91		

The pathway contributions of this dose are given in Table 10.

*** MEAN INDIVIDUAL ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (MRAD/Y)	1.46E-05	1.24E-06	1.05E-07	3.32E-07	3.35E-06	3.13E-16	1.62E-15	1.02E-08	4.05E-06	3.51E-07
	4.65E-05	2.67E-07	4.87E-05	3.21E-09	5.21E-07	4.72E-19	7.66E-06	1.28E-04		
HIGH LET (MRAD/Y)	3.70E-05	.0	1.90E-05	5.89E-05	8.35E-06	.0	.0	3.04E-03	4.27E-05	1.35E-06
	4.27E-09	1.18E 05	.0	4.44E-08	1.36E-08	1.04E-19	2.67E-14	3.22E-03		
DOSE EQUIVALENT (MREM/Y)	7.55E-04	1.24E-06	3.79E-04	1.18E-03	1.70E-04	3.13E-16	1.62E-15	6.09E-02	8.58E-04	2.78E-05
	4.66E-05	2.36E-04	4.87E-05	8.91E-07	7.92E-07	2.55E-18	7.66E-06	6.46E-02		

RADON DAUGHTER EXPOSURE:
(WORKING LEVEL) 2.02E-09

AVERAGE GONADAL DOSES:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (MRAD)	6.91E-07	2.10E-05	2.66E-06	1.47E-06	6.65E-05	8.19E-15	4.05E-14	2.44E-07	9.34E-07	9.44E-06
	1.16E-03	3.91E-06	1.19E-03	1.94E-08	1.46E-05	1.10E-17	2.09E-04	2.66E-03		
HIGH LET (MRAD)	6.83E-08	.0	7.72E-08	4.16E-06	1.26E-04	.0	.0	1.59E-02	3.80E-06	3.38E-05
	3.81E-09	8.81E-06	.0	.0	1.41E-07	5.03E-19	1.05E-13	1.61E-02		
DOSE EQUIVALENT (MREM)	2.06E-06	2.10E-05	4.21E-06	8.46E-05	2.58E-03	8.19E-15	4.05E-14	.318	7.67E-05	6.85E-04
	1.16E-03	1.80E-04	1.19E-03	1.94E-08	1.75E-05	2.11E-17	2.09E-04	.324		

*** COLLECTIVE POPULATION ***

DOSE RATES:
WEIGHTED SUMS OF ORGAN DOSE RATES

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (PERSON RAD/Y)	4.73E-02	4.02E-03	6.00E-04	1.08E-03	1.09E-02	1.02E-12	5.26E-12	3.30E-05	1.31E-02	2.76E-03
	.151	8.67E-04	.158	1.04E-05	1.69E-03	1.53E-15	2.48E-02	.416		
HIGH LET (PERSON RAD/Y)	.120	.0	6.15E-02	.191	2.71E-02	.0	.0	9.88	.139	4.38E-03
	1.39E-05	3.82E-02	.0	1.44E-04	4.40E-05	3.37E-16	8.66E-11	10.5		
DOSE EQ. (PERSON REM/Y)	2.45	4.02E-03	1.23	3.82	.553	1.02E-12	5.26E-12	198.	2.78	9.03E-02
	.151	.765	.158	2.09E-03	2.57E-03	8.27E-15	2.48E-02	210.		

RADON DAUGHTER EXPOSURE:
(PERSON WORKING LEVEL) 6.56E-03

AVERAGE GONADAL DOSES:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (PERSON RAD)	2.24E-03	6.80E-02	8.63E-03	4.78E-03	.216	2.66E-11	1.31E-10	7.90E-04	2.70E-03	3.06E-02
	3.75	1.27E-02	3.87	6.29E-05	4.75E-02	3.58E-14	.679	8.69		
HIGH LET (PERSON RAD)	2.22E-04	.0	2.51E-04	1.35E-02	.408	.0	.0	51.6	1.23E-02	.110
	1.24E-05	2.86E-02	.0	.0	4.57E-04	1.63E-15	3.39E-10	52.2		
DOSE EQ. (PERSON REM)	6.67E-03	6.80E-02	1.36E-02	.275	8.37	2.66E-11	1.31E-10	1.03E+03	.249	2.22
	3.75	.585	3.87	6.29E-05	5.66E-02	6.84E-14	.679	1.05E+03		

Table 5. Risk/risk equivalent summary

EXAMPLE CASE

RISK/RISK EQUIVALENT SUMMARY

*** SELECTED INDIVIDUAL ***

Table values are the probability of the selected individual dying of the cancer.

LIFETIME FATAL CANCER RISK:

CANCERS:	R MARROW ULI WALL	ENDOST SI WALL	PULMNARY OVARIES	BREAST TESTES	LIVER SPLEEN	ST WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS TOTAL	BL WALL
LOW LET	1.57E-08	1.63E-09	3.88E-08	1.78E-08	6.06E-09	3.27E-09	5.17E-09	2.33E-09	1.30E-09	1.37E-09
	1.50E-09	6.09E-10	5.61E-10	6.72E-10	6.97E-10	5.47E-10	6.90E-10	3.68E-09	1.02E-07	
HIGH LET	4.99E-07	1.39E-07	2.62E-05	1.86E-08	2.27E-07	1.35E-10	5.69E-08	4.32E-09	2.89E-07	8.12E-09
	7.18E-10	6.08E-11	8.12E-09	8.12E-09	2.49E-07	8.12E-09	8.12E-09	3.96E-09	2.78E-05	
TOTAL	5.15E-07	1.40E-07	2.63E-05	3.65E-08	2.33E-07	3.41E-09	6.20E-08	6.66E-09	2.91E-07	9.49E-09
	2.21E-09	6.70E-10	8.68E-09	8.79E-09	2.50E-07	8.67E-09	8.81E-09	7.64E-09	2.79E-05	

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.22E-07

TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 2.80E-05

(= LOW LET TOTAL + HIGH LET TOTAL + Lung Risk from Radon Daughter)

AVERAGE LIFE LOSS PER PREMATURE DEATH:

CANCERS:	R MARROW ULI WALL	ENDOST SI WALL	PULMNARY OVARIES	BREAST TESTES	LIVER SPLEEN	ST WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS TOTAL	BL WALL
LOW LET (YR)	31.6	29.2	22.3	21.5	21.5	21.4	21.4	21.5	21.5	21.5
	21.5	21.5	21.5	21.5	21.5	21.5	21.4	28.2	23.7	
HIGH LET (YR)	29.1	23.4	23.0	21.5	21.4	21.5	21.4	21.5	21.4	21.4
	21.4	21.4	21.4	21.4	21.5	21.4	21.4	28.2	23.1	
COMBINED (YR)	29.2	23.5	23.0	21.5	21.4	21.4	21.4	21.5	21.4	21.4
	21.5	21.5	21.4	21.4	21.5	21.4	21.4	28.2	23.1	

AVG LIFE LOSS FROM RADON DAUGHTER EXPOSURE FOR LUNG 14.1

AVG LIFE LOSS FROM ALL EXPOSURES FOR LUNG 23.0

AVG LIFE LOSS FROM ALL EXPOSURES (TOTAL) 23.0

Contributions to these risks by pathway and nuclide are given in Tables 6 and 7.

FATAL CANCER RISK EQUIVALENT:

CANCERS:	R MARROW ULI WALL	ENDOST SI WALL	PULMNARY OVARIES	BREAST TESTES	LIVER SPLEEN	ST WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS TOTAL	BL WALL
(MREM/YR)	.158	.456	4.33	9.14E-03	.149	3.92E-03	5.13E-02	9.59E-03	.838	2.73E-02
	6.39E-03	3.85E-03	4.99E-02	5.05E-02	1.44	4.98E-02	5.06E-02	9.02E-03	1.33	

WHOLE BODY FATAL CANCER RISK EQ(MREM/YR) 1.33

LUNG RISK EQUIVALENT(MREM/YR) FROM RADON DAUGHTER EXPOSURE 2.01E-02

WHOLE BODY RISK EQ (MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.84E-03

PULMNARY RISK EQ (MREM/YR) FOR ALL EXPOSURES 4.35

WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 1.34

GENETIC RISKS:

LOW LET (EFFECTS/BIRTH) 2.13E-08

HIGH LET (EFFECTS/BIRTH) 2.80E-06

COMBINED (EFFECTS/BIRTH) 2.82E-06

GENETIC RISK EQUIVALENT:

(MREM/YR) .470

AVG LIFE LOSS FROM ALL EXPOSURES (TOTAL) 23.0

FATAL CANCER RISK EQUIVALENT:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
(MREM/YR)	.158	.456	4.33	9.14E-03	.149	3.92E-03	5.13E-02	9.59E-03	.838	2.73E-02
	6.39E-03	3.85E-03	4.99E-02	5.05E-02	1.44	4.98E-02	5.06E-02	9.02E-03	1.33	

WHOLE BODY FATAL CANCER RISK EQ(MREM/YR) 1.33
LUNG RISK EQUIVALENT(MREM/YR) FROM RADON DAUGHTER EXPOSURE 2.01E-02
WHOLE BODY RISK EQ (MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.84E-03
PULMNARY RISK EQ (MREM/YR) FOR ALL EXPOSURES 4.35
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 1.34

GENETIC RISKS:
LOW LET (EFFECTS/BIRTH) 2.13E-08
HIGH LET (EFFECTS/BIRTH) 2.80E-06
COMBINED (EFFECTS/BIRTH) 2.82E-06

GENETIC RISK EQUIVALENT:
(MREM/YR) .470

EXAMPLE CASE

RISK/RISK EQUIVALENT SUMMARY

*** MEAN INDIVIDUAL ***

Table values are the probability of a fatal cancer in the user supplied population ÷ the user supplied population.

LIFETIME FATAL CANCER RISK:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
LOW LET	4.02E-10	4.28E-11	9.02E-10	4.49E-10	1.53E-10	8.25E-11	1.31E-10	6.90E-11	3.27E-11	3.46E-11
	3.89E-11	1.54E-11	1.42E-11	1.68E-11	1.76E-11	1.39E-11	1.74E-11	9.23E-11	2.52E-09	
HIGH LET	3.97E-08	3.89E-09	5.18E-07	2.15E-09	2.59E-08	3.61E-11	6.54E-09	1.16E-09	3.33E-08	9.35E-10
	1.92E-10	1.62E-11	9.35E-10	9.35E-10	2.86E-08	9.35E-10	9.35E-10	4.55E-10	6.65E-07	
TOTAL	4.01E-08	3.93E-09	5.19E-07	2.60E-09	2.60E-08	1.19E-10	6.67E-09	1.23E-09	3.33E-08	9.69E-10
	2.31E-10	3.17E-11	9.49E-10	9.51E-10	2.86E-08	9.48E-10	9.52E-10	5.47E-10	6.67E-07	

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 3.42E-09
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 6.71E-07

(= LOW LET TOTAL + HIGH LET TOTAL + Lung Risk from Radon Daughter)

AVERAGE LIFE LOSS PER PREMATURE DEATH:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
LOW LET (YR)	31.4	29.0	22.4	21.5	21.5	21.4	21.4	21.5	21.5	21.5
	21.5	21.5	21.5	21.5	21.5	21.5	21.4	28.2	23.8	
HIGH LET (YR)	30.9	24.5	23.0	21.4	21.5	21.5	21.5	21.4	21.5	21.5
	21.4	21.4	21.5	21.5	21.5	21.5	21.5	28.2	23.3	
COMBINED (YR)	30.9	24.5	23.0	21.4	21.5	21.5	21.5	21.4	21.5	21.5
	21.4	21.5	21.5	21.5	21.5	21.5	21.5	28.2	23.3	

AVG LIFE LOSS FROM RADON DAUGHTER EXPOSURE FOR LUNG 14.1
AVG LIFE LOSS FROM ALL EXPOSURES FOR LUNG 22.9
AVG LIFE LOSS FROM ALL EXPOSURES (TOTAL) 23.2

FATAL CANCER RISK EQUIVALENT:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
(MREM/YR)	1.23E-02	1.28E-02	8.55E-02	6.51E-04	1.67E-02	1.37E-04	5.52E-03	1.77E-03	9.58E-02	2.79E-03
	6.66E-04	1.82E-04	5.45E-03	5.46E-03	.165	5.45E-03	5.47E-03	6.48E-04	3.19E-02	

WHOLE BODY FATAL CANCER RISK EQ(MREM/YR) 3.19E-02
LUNG RISK EQUIVALENT(MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.62E-04
WHOLE BODY RISK EQ (MREM/YR) FROM RADON DAUGHTER EXPOSURE 1.63E-04
PULMNARY RISK EQ (MREM/YR) FOR ALL EXPOSURES 8.60E-02

This risk equivalent rate is detailed by nuclide and pathway in Table 9.

	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
(MREM/YR)	1.23E-02	1.29E-02	8.55E-02	6.51E-04	1.67E-02	1.37E-04	5.52E-03	1.77E-03	9.58E-02	2.79E-03
	6.66E-04	1.82E-04	5.45E-03	5.46E-03	.165	5.45E-03	5.47E-03	6.48E-04	3.19E-02	

This risk equivalent rate is detailed by nuclide and pathway in Table 9.

WHOLE BODY FATAL CANCER RISK EQ(MREM/YR)	3.19E-02
LUNG RISK EQUIVALENT(MREM/YR) FROM RADON DAUGHTER EXPOSURE	5.62E-04
WHOLE BODY RISK EQ (MREM/YR) FROM RADON DAUGHTER EXPOSURE	1.63E-04
PULMNARY RISK EQ (MREM/YR) FOR ALL EXPOSURES	8.60E-02
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES	3.21E-02

GENETIC RISKS:

LOW LET (EFFECTS/BIRTH)	5.36E-10
HIGH LET (EFFECTS/BIRTH)	3.22E-07
COMBINED (EFFECTS/BIRTH)	3.22E-07

GENETIC RISK EQUIVALENT:
(MREM/YR) 5.37E-02

EXAMPLE CASE

RISK/RISK EQUIVALENT SUMMARY

*** COLLECTIVE POPULATION ***

Tabl values are the probability of a fatal cancer in the user supplied population.

This fatal cancer induction rate detailed by pathway and nuclide in Table 11.

COLLECTIVE FATAL CANCER RISK:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
LOW LET(DEATHS/YR)	1.85E-05	1.96E-06	4.13E-05	2.06E-05	7.00E-06	3.78E-06	5.99E-06	3.16E-06	1.50E-06	1.59E-06
	1.78E-06	7.07E-07	6.52E-07	7.69E-07	8.05E-07	6.35E-07	7.97E-07	4.23E-06	1.16E-04	
HIGH LET(DEATHS/YR)	1.82E-03	1.78E-04	2.38E-02	9.86E-05	1.19E-03	1.65E-06	3.00E-04	5.32E-05	1.52E-03	4.28E-05
	8.81E-06	7.45E-07	4.28E-05	4.28E-05	1.31E-03	4.28E-05	4.28E-05	2.09E-05	3.05E-02	
TOTAL (DEATHS/YR)	1.84E-03	1.80E-04	2.38E-02	1.19E-04	1.19E-03	5.44E-06	3.06E-04	5.64E-05	1.53E-03	4.44E-05
	1.06E-05	1.45E-06	4.35E-05	4.36E-05	1.31E-03	4.35E-05	4.36E-05	2.51E-05	3.06E-02	

LUNG CANCER RISK(DEATHS/YR) FROM RADON DAUGHTER EXPOSURE	1.57E-04
TOTAL FATAL CANCER RISK(DEATHS/YR) FROM ALL EXPOSURE	3.07E-02

Also given in Table 11.

Contributions to this cancer risk by distance and direction away from the source is given in Table 14.

FATAL CANCER RISK EQUIVALENT:

CANCERS:	R MARROW	ENDOST	PULMNARY	BREAST	LIVER	ST WALL	PANCREAS	LLI WALL	KIDNEYS	BL WALL
	ULI WALL	SI WALL	OVARIES	TESTES	SPLEEN	UTERUS	THYMUS	THYROID	TOTAL	
(PERSON REM/YR)	39.9	41.4	277.	2.11	54.2	.443	17.9	3.75	311.	9.04
	2.16	.591	17.7	17.7	534.	17.7	17.7	2.10	104.	

WHOLE BODY FATAL CANCER RISK EQ(PERSON REM/YR)	104.
LUNG RISK EQ. (PERSON REM/YR) FROM RADON DAUGHTER EXPOSURE	1.82
WHOLE BODY RISK EQ (PERSON REM/YR) FROM RADON DAUGHTER EXPOSURE	.530
PULMNARY RISK EQ (PERSON REM/YR) FOR ALL EXPOSURES	279.
WHOLE BODY RISK EQ (PERSON REM/YR) FROM ALL EXPOSURES	104.

GENETIC RISKS:

LOW LET(EFFECTS/YR)	2.46E-05
HIGH LET(EFFECTS/YR)	1.47E-02
COMBINED(EFFECTS/YR)	1.48E-02

GENETIC RISK EQUIVALENT:
(PERSON REM/YR) 174.

cancer risks and fatal cancer risk equivalents by organ or cancer for selected individuals, mean individuals, and the collective population summed over pathways and nuclides. Tables 6 and 7 are analogous to Table 5 except that risks and risk equivalents are summed by pathways (Table 6) and nuclides (Table 7).

2.4.2 Example detailed tables

An example of a type "a" table is displayed in Table 8. The factor tabulated is the selected individual dose rate for low-LET exposure. The values are for the ingestion pathway only and are summarized for each organ and cancer. Column totals are given.

Table 9 is an example of table type "d." The risk equivalent is tabulated for the mean individual for endosteal cancer. A total over pathways and a total over nuclides is included. Table type "f" is analogous to Table type "d," except the weighted sum doses, total risks or whole body risk equivalents are listed.

An example table type "e" is displayed in Table 10. The factor is the selected individual genetic dose at high-LET exposures for radionuclide U-238. It is tabulated by pathways and organs. Table type "g" is similar to this table; the only difference is that the values are summed over all nuclides.

Other example tables are given in Tables 11 and 12. Table 11 is for the fatal cancer risk; note the separate summary for working level values. Table 12 is for collective genetic effects.

2.4.3 Example location tables

An example of a location table type "h" is Table 13. This particular table lists locations for the total risk. The locations are defined at varied distances for 16 sectors of a circle surrounding the source.

Table 6. Pathway risk/risk equivalent summary (example case)

EXAMPLE CASE

PATHWAY RISK/RISK EQUIVALENT SUMMARY

*** SELECTED INDIVIDUAL ***

LIFETIME FATAL CANCER RISK:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET	3.35E-11	1.33E-08	4.44E-12	8.91E-08	1.33E-08	8.91E-08	1.02E-07
HIGH LET	1.18E-07	2.77E-05	.0	.0	2.78E-05	.0	2.78E-05
TOTAL	1.18E-07	2.77E-05	4.44E-12	8.91E-08	2.78E-05	8.91E-08	2.79E-05

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.22E-07
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 2.80E-05

Contributions to these risks by cancer and nuclide are given in Tables 5 and 7.

FATAL CANCER RISK EQUIVALENT:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
(MREM/YR)	5.67E-03	1.32	2.12E-07	4.26E-03	1.33	4.26E-03	1.33

WHOLE BODY RISK EQ(MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.84E-03
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 1.34

GENETIC RISKS:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET	3.35E-11	1.33E-08	4.44E-12	8.91E-08	1.33E-08	8.91E-08	1.02E-07
HIGH LET	1.18E-07	2.77E-05	.0	.0	2.78E-05	.0	2.78E-05
TOTAL	1.18E-07	2.77E-05	4.44E-12	8.91E-08	2.78E-05	8.91E-08	2.79E-05

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.22E-07
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 2.80E-05

Contributions to these risks by cancer and nuclide are given in Tables 5 and 7.

FATAL CANCER RISK EQUIVALENT:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
(MREM/YR)	5.67E-03	1.32	2.12E-07	4.26E-03	1.33	4.26E-03	1.33

WHOLE BODY RISK EQ(MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.84E-03
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 1.34

GENETIC RISKS:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (EFFECTS/BIRTH)	3.33E-12	1.16E-11	1.04E-12	2.13E-08	1.49E-11	2.13E-08	2.13E-08
HIGH LET (EFFECTS/BIRTH)	2.71E-07	2.53E-06	.0	.0	2.80E-06	.0	2.80E-06
COMBINED (EFFECTS/BIRTH)	2.71E-07	2.53E-06	1.04E-12	2.13E-08	2.80E-06	2.13E-08	2.82E-06

GENETIC RISK EQUIVALENT:

(MREM/YR)	4.52E-02	.422	1.74E-07	3.55E-03	.467	3.55E-03	.470

EXAMPLE CASE

PATHWAY RISK/RISK EQUIVALENT SUMMARY

***MEAN INDIVIDUAL ***

LIFETIME FATAL CANCER RISK:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET	3.35E-11	2.58E-10	9.28E-14	2.23E-09	2.92E-10	2.23E-09	2.52E-09
HIGH LET	1.18E-07	5.46E-07	.0	.0	6.65E-07	.0	6.65E-07
TOTAL	1.18E-07	5.47E-07	9.28E-14	2.23E-09	6.65E-07	2.23E-09	6.67E-07

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 3.42E-09
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 6.71E-07

FATAL CANCER RISK EQUIVALENT:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
(MREM/YR)	5.67E-03	2.62E-02	4.45E-09	1.07E-04	3.18E-02	1.07E-04	3.19E-02

WHOLE BODY RISK EQ(MREM/YR) FROM RADON DAUGHTER EXPOSURE 1.63E-04
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 3.21E-02

GENETIC RISKS:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (EFFECTS/BIRTH)	3.33E-12	2.18E-13	2.18E-14	5.32E-10	3.55E-12	5.32E-10	5.36E-10

GENETIC RISKS:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET (EFFECTS/BIRTH)	3.33E-12	2.18E-13	2.18E-14	5.32E-10	3.55E-12	5.32E-10	5.36E-10
HIGH LET (EFFECTS/BIRTH)	2.71E-07	5.04E-08	.0	.0	3.22E-07	.0	3.22E-07
COMBINED (EFFECTS/BIRTH)	2.71E-07	5.04E-08	2.18E-14	5.32E-10	3.22E-07	5.32E-10	3.22E-07
GENETIC RISK EQUIVALENT: (MREM/YR)	4.52E-02	8.39E-03	3.64E-09	8.87E-05	5.36E-02	8.87E-05	5.37E-02

EXAMPLE CASE

PATHWAY RISK/RISK EQUIVALENT SUMMARY

*** COLLECTIVE POPULATION ***

COLLECTIVE FATAL CANCER RISK:

Details of the pulmonary cancer risk contributing to this risk are given in Table 11.

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET(DEATHS/YR)	1.54E-06	1.19E-05	4.26E-09	1.02E-04	1.34E-05	1.02E-04	1.16E-04
HIGH LET(DEATHS/YR)	5.43E-03	2.50E-02	.0	.0	3.05E-02	.0	3.05E-02
TOTAL (DEATHS/YR)	5.43E-03	2.51E-02	4.26E-09	1.02E-04	3.05E-02	1.02E-04	3.06E-02

LUNG CANCER RISK(DEATHS/YR) FROM RADON DAUGHTER EXPOSURE 1.57E-04
TOTAL FATAL CANCER RISK(DEATHS/YR) FROM ALL EXPOSURE 3.07E-02

FATAL CANCER RISK EQUIVALENT:

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
(PERSON REM/YR)	18.4	84.8	1.44E-05	.347	103.	.347	104.

WHOLE BODY RISK EQ(PERSON REM/YR) FROM RADON DAUGHTER EXPOSURE .530
WHOLE BODY RISK EQ (PERSON REM/YR) FROM ALL EXPOSURES 104.

GENETIC RISKS(PERSON REM/YR):

PATHWAYS:	INGESTION	INHALATION	AIR IMMERSION	GROUND SURFACE	INTERNAL	EXTERNAL	TOTAL
LOW LET(EFFECTS/YR)	1.53E-07	9.99E-09	1.00E-09	2.44E-05	1.63E-07	2.44E-05	2.46E-05
HIGH LET(EFFECTS/YR)	1.24E-02	2.31E-03	.0	.0	1.47E-02	.0	1.47E-02
COMBINED(EFFECTS/YR)	1.24E-02	2.31E-03	1.00E-09	2.44E-05	1.47E-02	2.44E-05	1.48E-02
GENETIC RISK EQUIVALENT: (PERSON REM/YR)	147.	27.2	1.18E-05	.288	174.	.288	174.

Table 7. Nuclide risk/risk equivalent summary (example case)

EXAMPLE CASE

NUCLIDE RISK/RISK EQUIVALENT SUMMARY

*** SELECTED INDIVIDUAL ***

LIFETIME FATAL CANCER RISK:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET	9.83E-09	1.13E-09	2.68E-10	2.45E-10	3.05E-09	2.57E-19	1.33E-18	8.11E-12	2.22E-09	3.73E-10
	3.83E-08	2.25E-10	4.01E-08	2.41E-12	4.23E-10	3.11E-22	6.29E-09	1.02E-07		
HIGH LET	3.68E-07	.0	3.92E-07	5.52E-07	4.43E-08	.0	.0	2.59E-05	3.94E-07	3.50E-09
	5.19E-11	1.43E-07	.0	3.33E-10	3.72E-12	1.66E-23	7.42E-18	2.78E-05		
TOTAL	3.78E-07	1.13E-09	3.92E-07	5.52E-07	4.74E-08	2.57E-19	1.33E-18	2.59E-05	3.96E-07	3.87E-09
	3.83E-08	1.44E-07	4.01E-08	3.35E-10	4.27E-10	3.28E-22	6.29E-09	2.79E-05		

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.22E-07

TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 2.80E-05

Contributions to these risks by cancer and pathway are given in Tables 5 and 6.

FATAL CANCER RISK EQUIVALENT:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
(MREM/YR)	1.81E-02	5.41E-05	1.88E-02	2.64E-02	2.27E-03	1.23E-14	6.38E-14	1.24	1.89E-02	1.85E-04
	1.83E-03	6.87E-03	1.92E-03	1.60E-05	2.04E-05	1.57E-17	3.01E-04	1.33		

WHOLE BODY RISK EQ(MREM/YR) FROM RADON DAUGHTER EXPOSURE 5.84E-03

WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 1.34

GENETIC RISKS:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (EFFECTS/BIRTH)	5.50E-12	1.66E-10	3.67E-11	1.16E-11	8.21E-10	6.44E-20	3.18E-19	1.81E-12	6.93E-12	5.84E-12
	9.10E-09	2.96E-11	9.38E-09	1.38E-13	1.14E-10	8.52E-23	1.65E-09	2.13E-08		
HIGH LET (EFFECTS/BIRTH)	4.84E-11	.0	5.44E-11	4.02E-09	4.98E-09	.0	.0	2.78E-06	3.71E-09	2.39E-09
	3.82E-12	8.73E-09	.0	.0	2.82E-12	1.01E-23	2.09E-18	2.80E-06		
COMBINED (EFFECTS/BIRTH)	5.39E-11	1.66E-10	9.11E-11	4.03E-09	5.80E-09	6.44E-20	3.18E-19	2.78E-06	3.71E-09	2.40E-09
	9.10E-09	8.76E-09	9.38E-09	1.38E-13	1.17E-10	9.52E-23	1.65E-09	2.82E-06		

GENETIC RISK EQUIVALENT:

(MREM/YR)	8.98E-06	2.76E-05	1.52E-05	6.72E-04	9.66E-04	1.07E-14	5.30E-14	.463	6.19E-04	3.99E-04
	1.52E-03	1.46E-03	1.56E-03	2.31E-08	1.96E-05	1.59E-17	2.74E-04	.470		

EXAMPLE CASE

NUCLIDE RISK/RISK EQUIVALENT SUMMARY

*** MEAN INDIVIDUAL ***

LIFETIME FATAL CANCER RISK:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET	1.96E-10	2.59E-11	3.16E-12	5.15E-12	6.30E-11	6.54E-21	3.39E-20	2.12E-13	4.44E-11	1.72E-11
	9.73E-10	5.55E-12	1.02E-09	9.74E-14	1.09E-11	9.33E-24	1.60E-10	2.52E-09		
HIGH LET	7.34E-09	.0	3.74E-09	1.11E-08	1.55E-09	.0	.0	6.30E-07	7.92E-09	2.66E-10
	1.03E-12	2.87E-09	.0	9.31E-12	3.72E-12	1.66E-23	7.42E-18	6.65E-07		
TOTAL	7.53E-09	2.59E-11	3.75E-09	1.11E-08	1.61E-09	6.54E-21	3.39E-20	6.30E-07	7.96E-09	2.83E-10
	9.74E-10	2.87E-09	1.02E-09	9.38E-12	1.46E-11	2.59E-23	1.60E-10	6.67E-07		

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 3.42E-09
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 6.71E-07

FATAL CANCER RISK EQUIVALENT:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
(MREM/YR)	3.60E-04	1.24E-06	1.79E-04	5.31E-04	7.72E-05	3.13E-16	1.62E-15	3.01E-02	3.81E-04	1.36E-05
	4.66E-05	1.38E-04	4.88E-05	4.49E-07	6.99E-07	1.24E-18	7.66E-06	3.19E-02		

WHOLE BODY RISK EQ(MREM/YR) FROM RADON DAUGHTER EXPOSURE 1.63E-04
WHOLE BODY RISK EQ (MREM/YR) FROM ALL EXPOSURES 3.21E-02

GENETIC RISKS:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET (EFFECTS/BIRTH)	1.38E-13	4.19E-12	5.32E-13	2.95E-13	1.33E-11	1.64E-21	8.09E-21	4.87E-14	1.67E-13	1.89E-12
	2.31E-10	7.82E-13	2.39E-10	3.88E-15	2.93E-12	2.20E-24	4.19E-11	5.36E-10		
HIGH LET (EFFECTS/BIRTH)	1.37E-12	.0	1.54E-12	8.32E-11	2.51E-09	.0	.0	3.18E-07	7.59E-11	6.75E-10
	7.62E-14	1.76E-10	.0	.0	2.82E-12	1.01E-23	2.09E-18	3.22E-07		
COMBINED (EFFECTS/BIRTH)	1.50E-12	4.19E-12	2.08E-12	8.65E-11	2.53E-09	1.64E-21	8.09E-21	3.18E-07	7.61E-11	6.77E-10
	2.31E-10	1.77E-10	2.39E-10	3.88E-15	5.74E-12	1.23E-23	4.19E-11	3.22E-07		

GENETIC RISK EQUIVALENT:

(MREM/YR)	2.51E-07	6.98E-07	3.46E-07	1.39E-05	4.21E-04	2.73E-16	1.35E-15	5.30E-02	1.27E-05	1.13E-04
	3.86E-05	2.95E-05	3.98E-05	6.46E-10	9.57E-07	2.04E-18	6.98E-06	5.37E-02		

EXAMPLE CASE

NUCLIDE RISK/RISK EQUIVALENT SUMMARY

*** COLLECTIVE POPULATION ***

COLLECTIVE FATAL CANCER RISK:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET(DEATHS/YR)	8.99E-06	1.19E-06	1.45E-07	2.36E-07	2.89E-06	3.00E-16	1.56E-15	9.74E-09	2.04E-06	7.87E-07
	4.46E-05	2.55E-07	4.68E-05	3.09E-09	4.99E-07	4.28E-19	7.34E-06	1.16E-04		
HIGH LET(DEATHS/YR)	3.36E-04	.0	1.72E-04	5.09E-04	7.11E-05	.0	.0	2.89E-02	3.63E-04	1.22E-05
	4.74E-08	1.32E-04	.0	4.27E-07	1.71E-07	7.60E-19	3.40E-13	3.05E-02		
TOTAL (DEATHS/YR)	3.45E-04	1.19E-06	1.72E-04	5.09E-04	7.40E-05	3.00E-16	1.56E-15	2.89E-02	3.65E-04	1.30E-05
	4.47E-05	1.32E-04	4.68E-05	4.30E-07	6.70E-07	1.19E-18	7.34E-06	3.06E-02		

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.57E-04
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 3.07E-02

FATAL CANCER RISK EQUIVALENT:

NUCLIDE RISK/RISK EQUIVALENT SUMMARY

*** COLLECTIVE POPULATION ***

COLLECTIVE FATAL CANCER RISK:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET(DEATHS/YR)	8.99E-06	1.19E-06	1.45E-07	2.36E-07	2.89E-06	3.00E-16	1.56E-15	9.74E-09	2.04E-06	7.87E-07
	4.46E-05	2.55E-07	4.68E-05	3.09E-09	4.99E-07	4.28E-19	7.34E-06	1.16E-04		
HIGH LET(DEATHS/YR)	3.36E-04	.0	1.72E-04	5.09E-04	7.11E-05	.0	.0	2.89E-02	3.63E-04	1.22E-05
	4.74E-08	1.32E-04	.0	4.27E-07	1.71E-07	7.60E-19	3.40E-13	3.05E-02		
TOTAL (DEATHS/YR)	3.45E-04	1.19E-06	1.72E-04	5.09E-04	7.40E-05	3.00E-16	1.56E-15	2.89E-02	3.65E-04	1.30E-05
	4.47E-05	1.32E-04	4.68E-05	4.30E-07	6.70E-07	1.19E-18	7.34E-06	3.06E-02		

LUNG CANCER RISK FROM RADON DAUGHTER EXPOSURE 1.57E-04
TOTAL FATAL CANCER RISK FROM ALL EXPOSURES 3.07E-02

FATAL CANCER RISK EQUIVALENT:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
(PERSON REM/YR)	1.17	4.02E-03	.582	1.72	.251	1.02E-12	5.27E-12	97.8	1.24	4.40E-02
	.151	.446	.158	1.46E-03	2.27E-03	4.02E-15	2.48E-02	104.		

WHOLE BODY RISK EQ(PERSON REM/YR) FROM RADON DAUGHTER EXPOSURE .530
WHOLE BODY RISK EQ (PERSON REM/YR) FROM ALL EXPOSURES 104.

Table 12 repeats this list giving the percent each number contributes to the TOTAL LOW LET risk.

GENETIC RISKS:

NUCLIDES:	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
LOW LET(EFFECTS/YR)	6.33E-09	1.92E-07	2.44E-08	1.35E-08	6.09E-07	7.51E-17	3.71E-16	2.23E-05	7.64E-09	8.65E-08
	1.06E-05	3.58E-08	1.09E-05	1.78E-10	1.34E-07	1.01E-19	1.92E-06	2.46E-05		
HIGH LET(EFFECTS/YR)	6.27E-08	.0	7.08E-08	3.81E-06	1.15E-04	.0	.0	1.46E-02	3.48E-06	3.10E-05
	3.49E-09	8.08E-06	.0	.0	1.29E-07	4.61E-19	9.59E-14	1.47E-02		
COMBINED(EFFECTS/YR)	6.90E-08	1.92E-07	9.52E-08	3.83E-06	1.16E-04	7.51E-17	3.71E-16	1.46E-02	3.49E-06	3.10E-05
	1.06E-05	8.12E-06	1.09E-05	1.78E-10	2.63E-07	5.62E-19	1.92E-06	1.48E-02		

GENETIC RISK EQUIVALENT:

(PERSON REM/YR)	8.14E-04	2.27E-03	1.12E-03	4.51E-02	1.37	8.86E-13	4.38E-12	172.	4.11E-02	.366
	.125	9.57E-02	.129	2.10E-06	3.11E-03	6.63E-15	2.26E-02	174.		

Table 8. Individual dose rate (mrad/yr) (example case)

EXAMPLE CASE
INDIVIDUAL DOSE RATE (MRAD/YEAR)
LOW LET

*** FOR PATHWAY: INGESTION (See Table 3)

ORGAN →	R MAR ULI WALL	ENDOST SI WALL	*PUL* OVARIES	MUSCLE TESTES	LIVER SPLEEN	S WALL UTERUS	PANCREAS THYMUS	LLI WALL THYROID	KIDNEYS	BL WALL
NUCLIDES										
U-238	2.76E-08	5.61E-08	3.92E-11	2.02E-10	1.74E-10	1.13E-09	1.93E-10	2.79E-07	1.70E-08	1.31E-10
	4.95E-08	4.52E-09	4.15E-10	1.73E-10	1.89E-10	2.22E-10	1.75E-10	1.72E-10		
% OF TOTAL INGESTION	.532	.546	9.14E-03	3.14E-02	3.45E-02	.283	3.00E-02	1.75	2.70	2.78E-02
	1.20	.451	4.56E-02	3.37E-02	3.67E-02	3.34E-02	3.51E-02	3.67E-02		
% OF TOTAL INTERNAL	9.57E-02	9.53E-02	1.15E-06	3.21E-03	1.74E-03	1.50E-02	2.16E-03	.337	.220	5.92E-03
	.168	5.73E-02	9.83E-03	6.88E-03	2.39E-03	6.42E-03	1.38E-03	3.35E-03		
% OF TOTAL	5.72E-04	1.05E-03	5.14E-07	4.52E-06	4.47E-06	3.27E-05	4.54E-06	8.31E-03	4.54E-04	3.30E-06
	1.15E-03	1.29E-04	1.28E-05	4.47E-06	4.69E-06	7.03E-06	4.40E-06	3.96E-06		
TH-234	1.05E-09	9.34E-10	3.77E-11	2.94E-10	3.49E-10	8.79E-08	2.99E-10	3.80E-06	3.10E-10	7.12E-10
	1.30E-06	2.25E-07	2.41E-09	2.08E-10	2.48E-10	1.02E-09	6.85E-11	3.82E-11		
% OF TOTAL INGESTION	2.03E-02	9.09E-03	8.79E-03	4.56E-02	6.91E-02	20.2	4.65E-02	23.6	4.92E-02	.151
	31.6	22.5	.265	4.05E-02	4.83E-02	.154	9.72E-03	8.15E-03		
% OF TOTAL INTERNAL	3.65E-03	1.59E-03	1.11E-06	4.62E-03	3.50E-03	1.07	3.35E-03	4.58	4.01E-03	3.22E-02
	4.41	2.86	5.71E-02	8.27E-03	3.15E-03	2.96E-02	3.83E-04	7.43E-04		
% OF TOTAL	2.18E-05	1.76E-05	4.94E-07	6.58E-06	8.97E-06	2.33E-03	7.02E-06	.113	8.29E-06	1.80E-05
	3.02E-02	6.41E-03	7.45E-05	5.37E-06	6.17E-06	3.24E-05	1.22E-06	8.80E-07		
U-234	2.66E-10	1.11E-09	1.68E-12	1.63E-11	8.96E-12	3.01E-09	1.22E-11	1.33E-07	5.22E-10	1.61E-11
	4.46E-08	2.93E-09	3.43E-10	2.82E-12	9.81E-12	2.50E-11	5.86E-12	5.44E-12		
% OF TOTAL INGESTION	5.13E-03	1.08E-02	3.91E-04	2.54E-03	1.78E-03	.692	1.90E-03	.831	8.28E-02	3.42E-03
	1.08	.792	3.77E-02	1.53E-03	1.91E-03	3.76E-03	1.17E-03	1.16E-03		
% OF TOTAL INTERNAL	9.24E-04	1.89E-03	4.92E-08	2.60E-04	8.99E-05	3.66E-02	1.37E-04	.160	6.75E-03	7.29E-04
	.151	.101	8.13E-03	3.13E-04	1.24E-04	7.22E-04	4.63E-05	1.06E-04		
% OF TOTAL	5.52E-06	2.09E-05	2.20E-08	3.66E-07	2.31E-07	8.00E-05	2.88E-07	3.94E-03	1.40E-05	4.06E-07
	1.03E-03	2.26E-04	1.06E-05	2.03E-07	2.44E-07	7.91E-07	1.47E-07	1.25E-07		
TH-230	5.66E-10	3.03E-09	4.21E-12	3.84E-11	8.93E-11	1.47E-09	2.80E-11	6.44E-08	2.66E-11	2.78E-11
	2.16E-08	3.81E-09	1.71E-10	2.28E-11	2.54E-11	4.55E-11	2.00E-11	1.98E-11		
% OF TOTAL INGESTION	1.09E-02	2.95E-02	9.80E-04	4.41E-03	1.77E-02	.338	4.37E-03	.404	4.22E-03	5.90E-03
	.524	.380	1.88E-02	4.43E-03	4.94E-03	6.84E-03	4.01E-03	4.22E-03		
% OF TOTAL INTERNAL	1.96E-03	5.15E-03	1.23E-07	4.52E-04	8.97E-04	1.79E-02	3.15E-04	7.77E-02	3.44E-04	1.26E-03
	7.32E-02	4.83E-02	4.05E-03	9.07E-04	3.23E-04	1.31E-03	1.58E-04	3.85E-04		
% OF TOTAL	1.17E-05	5.70E-05	5.51E-08	6.36E-07	2.30E-06	3.91E-05	5.60E-07	1.92E-03	7.11E-07	7.01E-07
	5.01E-04	1.08E-04	5.29E-06	5.88E-07	6.32E-07	1.44E-06	5.03E-07	4.55E-07		
RA-226	4.13E-06	8.25E-06	3.11E-07	3.69E-07	2.46E-07	2.12E-07	3.48E-07	6.75E-06	3.27E-07	2.57E-07
	1.31E-06	4.20E-07	4.82E-07	2.70E-07	2.54E-07	2.85E-07	2.20E-07	2.42E-07		
% OF TOTAL INGESTION	79.7	80.3	72.4	57.4	48.7	47.6	54.2	42.3	51.9	54.6
	31.9	41.9	53.0	52.6	49.3	42.9	44.0	51.8		
% OF TOTAL INTERNAL	14.3	14.0	9.12E-03	2.98	2.47	2.57	3.91	8.14	4.23	11.6
	4.45	5.32	11.4	10.8	3.22	8.23	1.74	4.72		
% OF TOTAL	8.56E-04	.155	4.07E-03	8.22E-03	6.32E-03	5.61E-03	8.19E-03	.201	8.74E-03	6.49E-03
	3.04E-02	1.20E-02	1.49E-02	6.98E-03	6.31E-03	9.01E-03	5.52E-03	5.58E-03		
PB-214	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INGESTION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INTERNAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

	. -	. -	. -	3.66E-07	2.31E-07	8.00E-05	2.88E-07	3.94E-03	1.46E-05	4.06E-07
	1.03E-03	2.26E-04	1.06E-05	2.03E-07	2.44E-07	7.91E-07	1.47E-07	1.25E-0		
TH-230	5.66E-10	3.03E-09	4.21E-12	2.84E-11	8.93E-11	1.47E-09	2.80E-11	6.44E-08	2.66E-11	2.78E-11
	2.16E-08	3.81E-09	1.71E-10	2.28E-11	2.54E-11	4.55E-11	2.00E-11	1.98E-11		
% OF TOTAL INGESTION	1.09E-02	2.95E-02	9.80E-04	4.41E-03	1.77E-02	.338	4.37E-03	.404	4.22E-03	5.90E-03
	.524	.380	1.88E-02	4.43E-03	4.94E-03	6.84E-03	4.01E-03	4.22E-03		
% OF TOTAL INTERNAL	1.96E-03	5.15E-03	1.23E-07	4.52E-04	8.97E-04	1.79E-02	3.15E-04	7.77E-02	3.44E-04	1.26E-03
	7.32E-02	4.83E-02	4.05E-03	9.07E-04	3.23E-04	1.31E-03	1.58E-04	3.85E-04		
% OF TOTAL	1.17E-05	5.70E-05	5.51E-08	6.36E-07	2.30E-06	3.91E-05	6.60E-07	1.92E-03	7.11E-07	7.01E-07
	5.01E-04	1.08E-04	5.29E-06	5.88E-07	6.32E-07	1.44E-06	5.03E-07	4.55E-07		
RA-226	4.13E-06	8.25E-06	3.11E-07	3.69E-07	2.46E-07	2.12E-07	3.48E-07	6.75E-06	3.27E-07	2.57E-07
	1.31E-06	4.20E-07	4.82E-07	2.70E-07	2.54E-07	2.85E-07	2.20E-07	2.42E-07		
% OF TOTAL INGESTION	79.7	80.3	72.4	57.4	48.7	48.6	54.2	42.3	51.9	54.6
	31.9	41.9	53.0	52.6	49.3	42.9	44.0	51.8		
% OF TOTAL INTERNAL	14.3	14.0	9.12E-03	5.88	2.47	2.57	3.91	8.14	4.23	11.6	
	4.45	5.32	11.4	10.8	3.22	8.23	1.74	4.72		
% OF TOTAL	8.56E-02	.155	4.07E-03	8.22E-03	6.32E-03	5.61E-03	8.19E-03	.201	8.74	6.49E-03
	3.04E-02	1.20E-02	1.49E-02	6.98E-03	6.31E-03	9.01E-03	5.52E-03	5.58E-03		
PB-214	.0	0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INGESTION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INTERNAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
BI-214	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INGESTION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INTERNAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	0	.0	.0	.0	.0		
PO-210	3.26E-10	2.07E-10	1.97E-10	2.44E-10	5.37E-10	4.51E-10	6.43E-10	1.35E-09	1.28E-09	3.28E-10
	9.08E-10	7.03E-10	7.30E-10	1.85E-10	1.97E-09	6.00E-10	2.63E-10	1.39E-10		
% OF TOTAL INGESTION	6.29E-03	2.01E-03	4.58E-02	3.80E-02	.106	.104	.100	8.45E-03	.203	6.97E-02
	2.20E-02	7.01E-02	8.03E-02	3.59E-02	.382	9.03E-02	5.28E-02	2.98E-02		
% OF TOTAL INTERNAL	1.13E-03	3.51E-04	5.76E-06	3.89E-03	5.39E-03	5.48E-03	7.21E-03	1.63E-03	1.66E-02	1.49E-02
	3.73E-03	8.91E-03	1.73E-02	7.35E-03	2.49E-02	1.73E-02	2.08E-03	2.71E-03		
% OF TOTAL	6.76E-06	3.89E-06	2.58E-06	5.47E-06	1.38E-05	1.20E-05	1.51E-05	4.01E-05	3.42E-05	8.28E-06
	2.10E-05	2.00E-05	2.26E-05	4.77E-06	4.89E-05	1.90E-05	6.61E-06	3.21E-06		
TH-232	1.79E-09	4.85E-09	1.32E-10	1.71E-10	1.83E-10	1.00E-09	1.59E-10	4.17E-08	1.64E-10	9.69E-11
	1.38E-08	2.54E-09	2.58E-10	1.18E-10	1.30E-10	1.44E-10	1.22E-10	1.12E-10		
% OF TOTAL INGESTION	3.45E-02	4.71E-02	3.08E-02	2.65E-02	3.63E-02	.230	2.48E-02	.261	2.60E-02	2.06E-02
	.336	.253	2.83E-02	2.29E-02	2.53E-02	2.16E-02	2.45E-02	2.40E-02		
% OF TOTAL INTERNAL	6.21E-03	8.23E-03	3.88E-06	2.71E-03	1.84E-03	1.22E-02	1.78E-03	5.02E-02	2.12E-03	4.39E-03
	4.69E-02	1.22E-02	6.11E-03	4.69E-03	1.65E-03	4.15E-03	9.66E-04	2.18E-03		
% OF TOTAL	3.71E-05	11E-05	1.73E-06	3.82E-06	4.71E-06	2.66E-05	3.74E-06	1.24E-03	4.38E-06	2.45E-06
	3.21E-04	7.23E-05	7.97E-06	3.04E-06	3.24E-06	4.55E-06	3.07E-06	2.58E-06		
RA-228	1.02E-06	1.96E-06	1.18E-07	2.71E-07	2.55E-07	1.24E-07	2.91E-07	4.09E-06	2.82E-07	2.06E-07
	1.25E-06	3.18E-07	4.04E-07	2.40E-07	2.57E-07	3.71E-07	2.78E-07	2.25E-07		
% OF TOTAL INGESTION	19.6	19.0	27.4	42.1	50.6	28.6	45.3	25.7	44.7	43.8
	30.3	31.7	44.4	46.8	49.8	55.8	55.7	48.1		
% OF TOTAL INTERNAL	3.53	3.33	3.45E-03	4.31	2.56	1.31	3.27	4.94	3.65	9.33
	4.24	4.03	9.58	9.57	3.25	10.7	2.20	4.38		
% OF TOTAL	2.11E-02	3.68E-02	1.54E-03	6.07E-03	6.57E-03	3.30E-03	6.85E-03	.122	7.53E-03	5.20E-03
	2.90E-02	9.05E-03	1.25E-02	6.21E-03	6.38E-03	1.17E-02	6.98E-03	5.19E-03		
AC-228	1.20E-18	4.20E-19	2.55E-19	8.02E-19	9.78E-19	2.05E-17	1.75E-18	6.07E-17	1.35E-18	1.42E-18
	7.93E-17	3.69E-17	5.08E-18	3.70E-19	1.17E-18	2.94E-18	1.06E-19	3.27E-20		
% OF TOTAL INGESTION	2.32E-11	4.08E-12	5.95E-11	1.25E-10	1.94E-10	4.70E-09	2.73E-10	3.80E-10	2.14E-10	3.01E-10
	1.92E-09	3.68E-09	5.58E-10	7.20E-11	2.28E-10	4.42E-10	2.13E-11	6.98E-12		
% OF TOTAL INTERNAL	4.17E-12	7.13E-13	7.49E-15	1.28E-11	9.81E-12	2.49E-10	1.97E-11	7.32E-11	1.75E-11	6.42E-11
	2.69E-10	4.67E-10	1.20E-10	1.47E-11	1.49E-11	8.49E-11	8.41E-13	6.37E-13		
% OF TOTAL	2.49E-14	7.19E-15	3.34E-15	1.80E-14	2.52E-14	5.44E-13	4.12E-14	1.81E-12	3.61E-14	3.58E-14
	1.84E-12	1.05E-12	1.57E-13	9.55E-15	2.91E-14	9.30E-14	2.67E-15	7.53E-16		

% OF TOTAL INGESTION	2.32E-11	4.08E-12	5.95E-11	1.25E-10	1.94E-10	4.70E-09	2.73E-10	3.80E-10	2.14E-10	3.01E-10
	1.92E-09	3.68E-09	5.58E-10	7.20E-11	2.28E-10	4.42E-10	2.13E-11	6.98E-12		
% OF TOTAL INTERNAL	4.17E-12	7.13E-13	7.49E-15	1.28E-11	9.81E-12	2.49E-10	1.97E-11	7.32E-11	1.75E-11	6.42E-11
	2.69E-10	4.67E-10	1.20E-10	1.47E-11	1.49E-11	8.49E-11	8.41E-14	6.37E-13		
% OF TOTAL	2.49E-14	7.89E-15	3.34E-15	1.80E-14	2.52E-14	5.44E-13	4.12E-14	1.81E-12	3.61E-14	3.58E-14
	1.84E-12	1.05E-12	1.57E-13	9.55E-15	2.91E-14	9.30E-14	2.67E-15	7.53E-16		
TH-228	3.68E-09	2.61E-09	2.83E-10	1.71E-09	1.03E-09	3.60E-09	1.10E-09	6.45E-07	1.42E-09	4.88E-09
	8.67E-08	1.39E-08	1.48E-08	1.77E-09	1.13E-09	5.33E-09	2.55E-10	1.60E-10		
% OF TOTAL INGESTION	7.09E-02	2.54E-02	6.60E-02	.266	.204	.827	.172	4.04	.225	1.04
	2.10	1.39	1.63	.344	.219	.802	5.11E-02	3.41E-02		
% OF TOTAL INTERNAL	1.28E-02	4.43E-03	8.31E-06	2.72E-02	1.03E-02	4.37E-02	1.24E-02	.778	1.83E-02	.221
	.294	.177	.350	7.03E-02	1.43E-02	.154	2.02E-03	3.11E-03		
% OF TOTAL	7.62E-05	4.90E-05	3.71E-06	3.83E-05	2.65E-05	9.55E-05	2.59E-05	1.92E-02	3.79E-05	1.23E-04
	2.01E-03	3.97E-04	4.57E-04	4.56E-05	2.80E-05	1.69E-04	6.41E-06	3.68E-06		
TL-208	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INGESTION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INTERNAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
RN-222	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INGESTION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL INTERNAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
% OF TOTAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	.0	.0	.0	.0	.0	.0	.0	.0		
RA-224	1.37E-09	1.20E-09	1.43E-10	6.60E-10	7.98E-10	9.71E-10	5.84E-10	1.47E-07	8.24E-10	1.45E-09
	3.90E-08	5.28E-09	4.44E-09	6.20E-10	5.14E-10	1.82E-09	2.57E-10	1.79E-10		
% OF TOTAL INGESTION	2.64E-02	1.17E-02	3.32E-02	.103	.158	.223	9.09E-02	.920	.131	.308
	.947	.528	.488	.121	9.99E-02	.274	5.15E-02	3.82E-02		
% OF TOTAL INTERNAL	4.74E-03	2.05E-03	4.18E-06	1.05E-02	8.02E-03	1.18E-02	6.55E-03	.177	1.07E-02	6.56E-02
	.132	6.70E-02	.105	2.47E-02	6.52E-03	5.26E-02	2.03E-03	3.48E-03		
% OF TOTAL	2.83E-05	2.27E-05	1.87E-06	1.48E-05	2.05E-05	2.58E-05	1.37E-05	4.37E-03	2.20E-05	3.66E-05
	9.04E-04	1.50E-04	1.37E-04	1.60E-05	1.28E-05	5.76E-05	6.46E-06	4.12E-06		
PB-210	3.41E-19	9.18E-19	5.84E-22	9.96E-21	2.52E-19	1.32E-21	1.02E-20	1.13E-19	1.18E-19	4.91E-21
	2.41E-20	3.05E-21	1.01E-20	9.70E-21	9.49E-21	9.83E-21	9.84E-21	9.85E-21		
% OF TOTAL INGESTION	6.57E-12	8.93E-12	1.36E-13	1.55E-12	4.99E-11	3.02E-13	1.59E-12	7.10E-13	1.87E-11	1.04E-12
	5.84E-13	3.05E-13	1.11E-12	1.89E-12	1.84E-12	1.48E-12	1.97E-12	2.10E-12		
% OF TOTAL INTERNAL	1.18E-12	1.56E-12	1.71E-17	1.58E-13	2.53E-12	1.60E-14	1.14E-13	1.37E-13	1.52E-12	2.22E-13
	8.16E-14	3.87E-14	2.39E-13	3.86E-13	1.20E-13	2.84E-13	7.78E-14	1.92E-13		
% OF TOTAL	7.06E-15	1.73E-14	7.66E-18	2.23E-16	6.47E-15	3.50E-17	2.40E-16	3.37E-15	3.15E-15	1.24E-16
	5.58E-16	8.70E-17	3.11E-16	2.51E-16	2.30E-16	3.11E-16	2.47E-16	2.27E-16		
PB-212	7.98E-15	8.04E-15	1.28E-15	3.71E-15	1.52E-14	3.88E-14	5.45E-15	4.18E-13	1.18E-14	6.37E-15
	3.61E-13	1.07E-13	2.14E-14	2.61E-15	3.80E-15	1.06E-14	1.49E-15	9.17E-16		
% OF TOTAL INGESTION	1.54E-07	7.83E-08	2.98E-07	5.76E-07	3.01E-06	8.90E-06	8.48E-07	2.62E-06	1.87E-06	1.35E-06
	8.76E-06	1.07E-05	2.35E-06	5.09E-07	7.39E-07	1.60E-06	2.98E-07	1.96E-07		
% OF TOTAL INTERNAL	2.77E-08	1.37E-08	3.75E-11	5.90E-08	1.53E-07	4.71E-07	6.11E-08	5.04E-07	1.53E-07	2.88E-07
	1.22E-06	1.36E-06	5.06E-07	1.04E-07	4.82E-08	3.08E-07	1.18E-08	1.78E-08		
% OF TOTAL	1.65E-10	1.51E-10	1.68E-11	8.30E-11	3.91E-10	1.03E-09	1.28E-10	1.24E-08	3.16E-10	1.61E-10
	8.37E-09	3.05E-09	6.60E-10	6.75E-11	9.45E-11	3.37E-10	3.74E-11	2.11E-11		
TOTAL	5.19E-06	1.03E-05	4.29E-07	6.44E-07	5.04E-07	4.36E-07	6.43E-07	1.60E-05	6.31E-07	4.71E-07
	4.12E-06	1.00E-06	9.09E-07	5.14E-07	5.15E-07	6.65E-07	4.99E-07	4.69E-07		

Table 9. Mean individual risk equivalent rate (mrem/yr) (example case)

EXAMPLE CASE
MEAN INDIVIDUAL RISK EQ. RATE(MREM/YEAR)

***FOR CANCER :ENDOST (See Table 5.)

NUCLIDES	U-238	TH-234	U-234	TH-230	RA-226	PB-214	BI-214	PO-210	TH-232	RA-228
	AC-228	TH-228	TL-208	RN-222	RA-224	PB-210	PB-212	TOTAL		
PATHWAYS										
INGESTION	1.17E-06	9.34E-10	2.98E-06	1.41E-04	1.24E-03	.0	.0	2.09E-03	1.09E-04	1.52E-04
	1.07E-17	1.26E-05	.0	.0	2.89E-06	1.35E-17	4.58E-12	3.75E-03		
% OF INTERNAL	28.6	47.9	65.6	3.61	99.1	.0	.0	84.3	3.40	94.7
	1.85E-09	.762	.0	.0	100.	100.	100.	29.7		
% OF ALL PATHWAYS	28.5	5.14E-02	63.8	3.61	98.8	.0	.0	84.3	3.40	94.7
	1.85E-11	.762	.0	.0	78.3	94.4	3.65E-05	29.4		
INHALATION	2.91E-06	1.02E-09	1.56E-06	3.76E-03	1.18E-05	.0	.0	3.88E-04	3.08E-03	8.60E-06
	5.79E-07	1.64E-03	8.02E-13	4.82E-08	.0	.0	.0	8.89E-03		
% OF INTERNAL	71.4	52.1	34.4	96.4	.944	.0	.0	15.7	96.6	5.34
	100.	99.2	100.	100.	.0	.0	.0	70.3		
% OF ALL PATHWAYS	70.9	5.59E-02	33.4	96.4	.941	.0	.0	15.7	96.6	5.34
	.998	99.2	1.47E-06	97.9	.0	.0	.0	69.6		
AIR IMMERSION	1.47E-13	1.48E-11	2.06E-13	1.50E-12	1.12E-11	.0	.0	1.49E-11	4.95E-13	9.90E-21
	1.88E-09	5.82E-12	2.28E-09	1.05E-09	.0	.0	.0	5.26E-09		
% OF EXTERNAL	5.80E-04	8.16E-04	1.59E-04	1.64E-03	3.20E-04	.0	.0	.128	1.36E-03	2.21E-04
	3.27E-03	2.58E-03	4.19E-03	100.	.0	.0	.0	4.01E-03		
% OF ALL PATHWAYS	3.58E-06	8.15E-04	4.40E-06	3.85E-08	8.88E-07	.0	.0	6.04E-07	1.55E-08	6.15E-15
	3.24E-03	3.52E-07	4.19E-03	2.13	.0	.0	.0	4.11E-05		
GROUND SURFACE	2.54E-08	1.82E-06	1.29E-07	9.14E-08	3.49E-06	4.60E-16	1.88E-15	1.16E-08	3.63E-08	4.48E-15
	5.75E-05	2.25E-07	5.44E-05	.0	8.02E-07	8.10E-19	1.25E-05	1.31E-04		
% OF EXTERNAL	100.	100.	100.	100.	100.	100.	100.	99.9	100.	100.
	100.	100.	100.	.0	100.	100.	100.	100.		
% OF ALL PATHWAYS	.619	99.9	2.76	2.34E-03	.277	100.	100.	4.71E-04	1.14E-03	2.79E-09
	99.0	1.36E-02	100.	.0	21.7	5.64	100.	1.03		
INTERNAL	4.08E-06	1.95E-09	4.55E-06	3.90E-03	1.26E-03	.0	.0	2.47E-03	3.19E-03	1.61E-04
	5.79E-07	1.65E-03	8.02E-13	4.82E-08	2.89E-06	1.35E-17	4.58E-12	1.26E-02		
% OF ALL PATHWAYS	99.4	.107	97.2	100.	99.7	.0	.0	100.	100.	100.
	.998	100.	1.47E-06	97.9	78.3	94.4	3.65E-05	99.0		
EXTERNAL	2.54E-08	1.82E-06	1.29E-07	9.14E-08	3.49E-06	4.60E-16	1.88E-15	1.17E-08	3.63E-08	4.48E-15
	5.75E-05	2.25E-07	5.44E-05	1.05E-09	8.02E-07	8.10E-19	1.25E-05	1.31E-04		
% OF ALL PATHWAYS	.619	99.9	2.76	2.34E-03	.277	100.	100.	4.71E-04	1.14E-03	2.79E-09
	99.0	1.36E-02	100.	2.13	21.7	5.64	100.	1.03		
TOTAL OVER ALL PATHWAYS	4.10E-06	1.82E-06	4.68E-06	3.90E-03	1.26E-03	4.60E-16	1.88E-15	2.47E-03	3.19E-03	1.61E-04
	5.80E-05	1.65E-03	5.44E-05	4.92E-08	3.70E-06	1.44E-17	1.25E-05	1.28E-02		

Table 10. High-LET individual genetic dose (mrad) (example case)

For nuclide: U-238 gonad pathways	Testes	Ovaries	Average
Ingestion	2.06E-08	2.05E-08	2.06E-08
Percent of internal	0.852	0.854	0.851
Percent of all pathways	0.852	0.854	0.851
Inhalation	2.40E-06	2.38E-06	2.40E-06
Percent of internal	99.1	99.1	99.1
Percent of all pathways	99.1	99.1	99.1
Air immersion	0	0	0
Percent of external	0	0	0
Percent of all pathways	0	0	0
Ground surface	0	0	0
Percent of external	0	0	0
Percent of all pathways	0	0	0
Internal	2.42E-06	2.40E-06	2.42E-06
Percent of all pathways	100	100	100
External	0	0	0
Percent of all pathways	0	0	0
Total over all pathways	2.42E-06	2.40E-06	2.42E-06
Percent of total	1.73E-03	1.72E-03	1.73E-03

Table 11. Low LET fatal cancer rate (death/yr) (example case)

EXAMPLE CASE
FATAL CANCER RATE (DEATH/YR) (for the user specified population)
LOW LET

***FOR CANCER :PULMNARY

NUCLIDES	U-238 AC-228	TH-234 TH-228	U-234 TL-208	TH-230 RN-222	RA-226 RA-224	PB-214 PB-210	BI-214 PB-212	PO-210 TOTAL	TH-232	RA-228
PATHWAYS										
INGESTION	6.99E-12	1.05E-11	3.86E-13	7.21E-13	5.19E-08	.0	.0	5.46E-11	1.67E-11	2.92E-08
	7.09E-20	7.83E-11	.0	.0	3.98E-11	1.06E-22	3.57E-16	8.13E-08		
% OF INTERNAL	7.83E-05	8.67E-03	5.29E-04	3.92E-04	96.1	.0	.0	22.6	8.43E-04	8.62
	3.01E-09	9.41E-02	.0	.0	100.	100.	100.	.688		
% OF ALL PATHWAYS	7.83E-05	2.75E-03	4.47E-04	3.69E-04	8.50	.0	.0	1.87	8.41E-04	8.62
	5.43E-13	6.82E-02	.0	.0	2.85E-02	.125	1.74E-08	.197		
INHALATION	8.93E-06	1.58E-07	7.30E-08	1.84E-07	2.11E-09	.0	.0	1.87E-10	1.98E-06	3.10E-07
	2.36E-09	8.31E-08	1.09E-11	2.20E-09	.0	.0	.0	1.17E-05		
% OF INTERNAL	100.	100.	100.	100.	3.90	.0	.0	77.4	100.	91.4
	100.	99.9	100.	100.	.0	.0	.0	99.3		
% OF ALL PATHWAYS	100.	41.3	84.6	94.2	.345	.0	.0	6.42	99.8	91.4
	1.80E-02	72.4	8.09E-05	90.7	.0	.0	.0	28.4		
AIR IMMERSION	1.49E-14	1.85E-12	2.49E-14	1.96E-13	1.79E-12	.0	.0	3.42E-12	6.02E-14	1.50E-21
	4.32E-10	8.32E-13	5.70E-10	2.26E-10	.0	.0	.0	1.24E-09		
% OF EXTERNAL	6.64E-04	8.24E-04	1.87E-04	1.72E-03	3.22E-04	.0	.0	.128	1.46E-03	2.20E-04
	3.31E-03	2.64E-03	4.23E-03	100.	.0	.0	.0	4.18E-03		
% OF ALL PATHWAYS	1.67E-07	4.83E-04	2.88E-05	1.00E-04	2.93E-04	.0	.0	.117	3.03E-06	4.44E-13
	3.31E-03	7.25E-04	4.23E-03	9.33	.0	.0	.0	2.99E-03		
GROUND SURFACE	2.24E-09	2.25E-07	1.33E-08	1.14E-08	5.56E-07	8.55E-17	4.57E-16	2.67E-09	4.13E-09	6.84E-16
	1.31E-05	3.15E-08	1.35E-05	.0	1.40E-07	8.48E-20	2.05E-06	2.95E-05		
% OF EXTERNAL	100.	100.	100.	100.	100.	100.	100.	99.9	100.	100.
	100.	100.	100.	.0	100.	100.	100.	100.		
% OF ALL PATHWAYS	2.51E-02	58.7	15.4	5.84	91.2	100.	100.	91.6	.208	2.02E-07
	100.	27.5	100.	.0	100.	99.9	100.	71.4		
INTERNAL	8.93E-06	1.58E-07	7.30E-08	1.84E-07	5.40E-08	.0	.0	2.42E-10	1.98E-06	3.39E-07
	2.36E-09	8.32E-08	1.09E-11	2.20E-09	3.98E-11	1.06E-22	3.57E-16	1.18E-05		
% OF ALL PATHWAYS	100.	41.3	84.6	94.2	8.85	.0	.0	8.29	99.8	100.
	1.80E-02	72.5	8.09E-05	90.7	2.85E-02	.125	1.74E-08	28.6		
EXTERNAL	2.24E-09	2.25E-07	1.33E-08	1.14E-08	5.56E-07	8.55E-17	4.57E-16	2.68E-09	4.13E-09	6.84E-16
	1.31E-05	3.15E-08	1.35E-05	2.26E-10	1.40E-07	8.48E-20	2.05E-06	2.95E-05		
% OF ALL PATHWAYS	2.51E-02	58.7	15.4	5.84	91.2	100.	100.	91.7	.208	2.02E-07
	100.	27.5	100.	9.33	100.	99.9	100.	71.4		
TOTAL OVER ALL PATHWAYS	8.93E-06	3.83E-07	8.63E-08	1.95E-07	6.10E-07	8.55E-17	4.57E-16	2.92E-09	1.99E-06	3.39E-07
	1.31E-05	1.15E-07	1.35E-05	2.42E-09	1.40E-07	8.50E-20	2.05E-06	4.13E-05		

(See Table 8.)

RADON DAUGHTER EXPOSURE RISK:
(DEATH/YR) 1.57E-04

Table 12. Low LET collective genetic effect (effect/yr) (example case)

EXAMPLE CASE
COLLECTIVE GENETIC EFFECT(EFFECTIVE/YR)
LOW LET

*** FOR ALL PATHWAYS: (See Table 7.)

GONAD :	AVERAGE
NUCLIDES	
U-238	6.33E-09
% OF TOTAL	2.58E-02
TH-234	1.92E-07
% OF TOTAL	.782
U-234	2.44E-08
% OF TOTAL	9.93E-02
TH-230	1.35E-08
% OF TOTAL	5.50E-02
RA-226	6.09E-07
% OF TOTAL	2.48
PB-214	7.51E-17
% OF TOTAL	3.06E-10
BI-214	3.71E-16
% OF TOTAL	1.51E-09
PO-210	2.23E-09
% OF TOTAL	9.09E-03
TH-232	7.64E-09
% OF TOTAL	3.11E-02
RA-228	8.65E-08
% OF TOTAL	.352
AC-228	1.06E-05
% OF TOTAL	43.2
TH-228	3.58E-08
% OF TOTAL	.146
TL-208	1.09E-05
% OF TOTAL	44.5
RN-222	1.78E-10
% OF TOTAL	7.23E-04
RA-224	1.34E-07
% OF TOTAL	.546
PB-210	1.01E-19
% OF TOTAL	4.11E-13
PB-212	1.92E-06
% OF TOTAL	7.81
TOTAL	2.46E-05

Table 13. Test case - fatal cancer rate (death/yr)

TEST CASE
FATAL CANCER RATE (DEATH/YR) *(in the user specified population)*
COMB.LET

FOR RADIONUCLIDE : WLSUM
AND ORGAN/CANCER :SUM
AND PATHWAY : ALL

DIRECTIONS: DISTANCE (METERS):	N	NNE	NE	ENE	E	ESE	SE	SSE
					(User specified "Selected Individual" location)			
750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	0.0	0.0	0.0	6.904E-04	0.0	0.0	0.0	0.0
3500	4.442E-04	5.074E-04	5.332E-04	3.682E-04	1.921E-04	0.0	3.975E-04	1.238E-04
7500	5.465E-04	1.027E-03	5.325E-04	4.359E-04	1.285E-04	5.567E-05	7.903E-05	7.161E-05
15000	2.354E-03	8.551E-04	4.489E-04	4.273E-04	3.273E-04	9.367E-05	9.966E-05	6.719E-05
30000	4.397E-04	5.590E-04	1.914E-04	1.817E-04	5.047E-04	1.417E-04	1.731E-04	4.961E-05
60000	2.010E-04	1.553E-04	1.147E-04	1.741E-04	1.519E-04	5.673E-05	6.032E-05	1.227E-04
SUM	3.986E-03	3.104E-03	1.821E-03	2.278E-03	1.304E-03	3.477E-04	8.096E-04	4.350E-04

DISTANCE (METERS):	S	SSW	SW	WSW	W	WNW	NW	NNW	SUM
750	3.094E-04	1.884E-04	2.960E-04	0.0	0.0	0.0	0.0	0.0	7.939E-04
1500	0.0	4.206E-04	2.621E-04	3.398E-04	0.0	4.983E-04	0.0	0.0	2.211E-03
3500	5.112E-05	5.782E-05	2.192E-04	4.196E-05	9.169E-06	1.217E-04	5.488E-05	4.637E-04	3.586E-03
7500	0.0	6.736E-05	4.428E-05	0.0	5.897E-05	4.115E-04	2.067E-04	5.010E-04	4.166E-03
15000	4.945E-04	1.715E-04	2.440E-05	7.022E-05	3.830E-04	1.244E-03	2.464E-03	2.388E-03	1.191E-02
30000	1.909E-04	8.197E-05	3.972E-05	2.497E-04	1.726E-04	2.490E-04	1.026E-03	1.019E-03	5.270E-03
60000	2.158E-04	6.124E-05	2.408E-05	2.656E-04	2.794E-04	2.499E-04	4.950E-04	1.815E-04	2.809E-03
SUM	1.262E-03	1.049E-03	9.098E-04	9.672E-04	9.031E-04	2.774E-03	4.247E-03	4.553E-03	3.075E-02

Contributions to this cancer risk from each cancer, pathway, and nuclide are given in Tables 5, 6, and 7.

3. PROGRAM SPECIFICATIONS

The DARTAB program is written in FORTRAN IV. Computing is done in single precision. Individual subprograms and COMMON regions are defined in this section. A program listing and sample run are contained in the attached microfiche.

3.1 Subroutine Descriptions

MAIN

The MAIN routine reads in user input options and sets up default values. The input options are described in the next section. The routines called from MAIN are RDSTOR, CHLOC, PREPDR, PREPHR, PREPRF.

RDSTOR

This subroutine reads, from unit 25, the dosimetric and health effects data file consisting of information on the dose rates, health risk, and risk equivalent factors for each radionuclide. The factors requested for the appropriate radionuclides are stored for use in later calculations.

FACOUT

This routine prints out the conversion factors used in the calculations.

CHLOC

This routine reads, from unit 26, in the exposure and intake data (as derived from the environmental transport code). If a specific percentage location for individual factors is to be used in the calculations, the total risk is summed and ordered to choose the location corresponding to the selected percentile of total risk. This routine calls VSORTP, an IMSL (1977) routine, to sort the total risks.

PREPDR

This routine sets up the dose rates conversion factor and titles for producing the tables for individual, mean individual, or collective

group dose rates. If necessary, the low- and high-LET dose rates are combined. MULT is called by this routine.

PREPRF

This routine sets up the risk equivalent factors, conversion factors, and titles necessary for producing tables of risk equivalent factors. MULT is called by this routine.

PREPHR

This routine sets up the health risk, conversion factors, and titles necessary for producing tables of health risks. The low- and high-LET risks are combined if requested. MULT is called by this routine.

MULT

The factors set up by PREPDR, PREPRF, or PREPHR are multiplied and transferred to DRTAB to produce the tables. This routine calls DRTAB.

DRTAB

This routine takes the factors that have been calculated and outputs the tables requested. Row and/or column sums are calculated and printed along with different percentiles.

ORGFAC

This routine reads the organ dose weighting factors to use in summing dose rates.

SUMMRY

This routine calculates and prints the dose rate summary tables.

SUMMR2

This routine calculates and prints the health risk/risk equivalent summary tables.

3.2 Common Regions

/COMEX/EXPP(20,20,40,4), POP(20,20),POPFAC,TOTFAC,NOL,NOU,NRL,NRU, IDIST(20),ILOC,JLOC

EXPP the exposure values dimensioned by distance from the source, sector, nuclide and pathway;

POP the population values dimensioned by sector and distance from the source;

POPFAC the reciprocal value of the population at position ILOC,JLOC;

TOTFAC the reciprocal value of the total population;

NOL beginning index of sector for simulation;

NOU end index of sector for simulation;

NRL beginning index of distance for simulation;

NRU end index of distance for simulation;

IDIST values of distance from the source for the simulations;

ILOC sector of the single location used for individual calculations;

JLOC distance of the single location used for individual calculations.

/COMOR/ORGN(20),NORGN,TIME(20),DOSE(20,40,4,2),DTABLE(7)

ORGN alphanumeric organ names;

NORGN number of organs;

TIME exposure time to use for the organ;

DOSE dose factors dimensioned by organ, nuclide, pathway, and LET;

DTABLE indicator for which dose rate tables are to be printed.

/LETFAC/HLET(20),LLET(20)

HLET relative biological effectiveness for the high-LET dose rates;

LLET relative biological effectiveness for the low-LET dose rates.

/COMCA/CANC(20),NCANC,RELABS(20),RISK(20,40,4,2),RTABLE(7),AGEX,
YRLL(20,40,4,2)

CANC alphanumeric organ names;

NCANC number of cancers;

RELABS indicator for using relative or absolute risk for a particular cancer;

RISK health risk factors dimensioned by cancer, radionuclide, pathway, and LET;

RTABLE indicator for which health risk tables are to be printed;

AGEX average life expectancy;

YRLL total years of life lost.

/COMRF/REF(20,40,4),FTABLE(7)

REF risk equivalent factors dimensioned by cancer, radionuclide, and pathway;

FTABLE indicator for which risk equivalent factor tables are to be printed.

/COMNU/NUCLID(40),NONCLD,PSIZE(40),RESP(40),GIABS(4,40),INDPOP

NUCLID alphanumeric radionuclide names;

NONCLD number of nuclides;

PSIZE particle size for radionuclide;

RESP respiratory clearance class for radionuclide;

GIABS GI absorption factor for radionuclide;

INDPOP indicator for individual or population run.

/COMLOC/RNLOC(10),OGLOC(10),PTLOC(10),FALOC(10),HLLOC(10),
LTABLE(10),NTLOC

RNLOC radionuclide for location table;

OGLOC organ/cancer for location table;

PTLOC pathway for location table;

FALOC factor to be printed for location table;

LTABLE indicator for selected individual, mean individual, or collective group;

NTLOC number of location tables.

/COMGEN/GEN(3),NGEN,GDOSE(3,40,4,2)GRISK(3,40,4,2),GENEFF, GRFAC(2)REPPER,GLLET(3),GHLET(3),GREF(3,40,4)

GEN genetic organ names;

NGEN number of organs to be considered for genetic effect;

GDOSE genetic dose factors;

GRISK genetic risk factors;

GENEFF indicator for output of genetic effects;

GRFAC genetic risk conversion factors;

REPPER replacement rate for population;

GLLET relative biological effect factor to use for low-LET genetic dose;

GHLET same as above for high-LET;

GREF genetic risk equivalent factors.

/COMRN/OREP(20),RREP(20),CREP(20),WLRN(20,20)RRISK,RREF(2), RYRLL,NOREP,NRREP,NCREP

OREP organs to consider for working level exposures;

RREP radionuclides to consider for working level exposures;

CREP cancers to consider for working level exposures;

WLRN working level exposures;

RRISK risk due to working level exposures;

RREF risk equivalent due to working level exposures;

RYRLL years of life lost due to working level exposures;

NOREP number of organs in OREP;

NRREP number of radionuclides in RREP;

NCREP number of cancers in CREP.

/COMUS/

This common region is defined differently depending on the subroutine. It allows arrays which are only needed within a subroutine to share the same allocation of core.

3.3 User Input for DARTAB

This input to the code provides the user with control of the processing of the exposure, dosimetric data, and tabulations of output. The input is typically through "NAMELIST" format. An example of the input is shown in Table 14.

1. Variables: TITLE

   Format: 20(A4)

TITLE is a descriptive title to be included at the head of each table.

2. Variables: ILOC,JLOC,PLOC,AGEX,ILET,DTABLE,RTABLE,FTABLE,OUTPUT, GSCFAC

   Format: Namelist INPUT

ILOC, JLOC are the i and j location (direction and distance) indices for the desired of the exposure array to use for the individual tables. If both are zero, then the location will be chosen according to PLOC. (Default: 0,0)

PLOC is the percentile of the total risk to use in choosing the location for the exposure array used for the individual tables. If PLOC=p, then the location used will be the one associated with the [p/100] th ordered value of the risk array. (Default: 100)

AGEX is the average lifetime expectancy in years. (Default: 70.7565)

ILET is an array dimensioned by 2. ILET(I) = 0 indicates that only separate high- and low-LET tables will be output; 1 indicates only a combined table will be output; 2 indicates both sets of table will be output. For ILET(1), dose rate tables are output accordingly, and for ILET(2), health risk tables are output. (Default: 1,1)

Table 14. Sample input file

```
//*  JOB CARD
//*CLASS CPU91=100S,IO=5.0,REGION=540K,PRINT=25
// EXEC FORTHCLG,REGION.FORT=540K,
// PARM.GO='EU=-1,DUMP=I',REGION.GO=540K
//FORT.SYSIN DD *
=DARTAB.NEW
//* FILE 25 IS DOSE AND RISK FACTOR FILE^a
//GO.FT25F001 DD UNIT=TAPE62,DISP=(OLD,PASS),
//  VOL=SER=X14301,LABEL=(1,SL),DSN=S.SY017603.NALL,
// DCB=(RECFM=VBS,LRECL=240,BLKSIZE=2440,DEN=4)
//* FILE 26 IS OUTPUT FROM AIRDOS-EPA^b
//GO.FT26F001 DD UNIT=TAPE8,DISP=(OLD,PASS),
// VOL=SER=X06517,LABEL=(1, NL),
// DCB=(RECFM=VBS,BLKSIZE=13030,LRECL=13026,DEN=2)
//GO.FT05F001 DD *
TEST CASE
 &INPUT PLOC=100.,ILET=1,1,DTABLE=4,4,4,4,4,4,4,
 RTABLE=4,4,4,4,4,4,4,FTABLE=4,4,4,4,4,4,4,&END
 &ORGAN NORGN=18,ORGN='LUNGS    ','R MAR    ','LIVER    ',
 'S WALL   ','LLI WALL','KIDNEYS ',
 'SPLEEN   ','THYROID','MUSCLE   ','T BODY   ',
 'RES LYM ','SI WALL  ','ULI WALL','OVARIES ','BONE      ','ENDOST   ',
 'TESTES   ','UTERUS   ',
 TIME=70,70,70,70,70,70,70,70,70,70,70,70,70,70,70,70,70,70&END
 &QFACTR HLET=20,20,20,20,20,20,20,20,20,20,20,20,20,20,20,20,20,20,
 LLET=1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,&END
 &CANCER NCANC=18,CANC='R MARROW','ENDOST   ','PULMNARY','BREAST   ','LIVER    ',
 'ST WALL ','PANCREAS','LLI WALL','KIDNEYS',
 'BL WALL ','ULI WALL','SI WALL ','OVARIES ',
 'TESTES   ','SPLEEN   ','UTERUS   ',
 'THYMUS   ','THYROID ',
 RELABS=1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,&END
 &GENTIC GENEFF=.TRUE.,GEN='TESTES   ','OVARIES ','AVERAGE ',
 NGEN=3,GRFAC=200,20000,REPPER=.014133,GLLET=1,1,1,
 GHLET=20,20,20,&END
 &RNUCLD=17,NUCLID='U-238    ','TH-234   ','U-234    ','TH-230   ','RA-226   ',
 'PB-214   ','BI-214   ','PO-210   ','TH-232   ','RA-228',
 'AC-228   ','TH-228   ','TL-208   ','RN-222   ' 'RA-224   ',
 'PB-210   ','PB-212   ',PSIZE=1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
 RESP='Y','Y','Y','Y','W','W','W','W','Y','W','W','W',
 'W','*','W','W','W',GIABS=0,.002,0,0,0,.0002,0,0,0,.002,0,
 0,.0002,0,0,0, 2,0,0,0,.2,0,0,0,.05,0,0,0,.1,0,0,0,.0002,0,0,
 0,.2,0,0,0,.0?1,0,0,0,.0001,0,0,0,.95,0,0,0,0,0,0,0,.2,0,0,
 0,.2,0,0,0,.2,0,0,&END
 &LOCTBL NTLOC=3,RNLOC='SUM      ','WORKLEVL','WLSUM    ',
 OGLOC='SUM      ','SUM      ',
 'SUM      ',PTLOC=7,7,7,FALOC=2,2,2,HLLOC=1,1,1,LTABLE=3,3,3,&END
 &ORGANF NORGB=10,ORGB='R MAR    ','PULMNARY','LUNGS    ',
 'MUSCLE   ','LLI WALL','S WALL   ','KIDNEYS ','LIVER    ',
 'SPLEEN   ','THYROID ',IPATH=5,1,2,5,5,5,5,5,5,5,5,
 ORGDAT=.169,.208,.208,.208,.104,.104,.0521,.0521,.0521,.0521,&END
/*
//
```

[a]Dose and risk factor file produced by RADRISK documented in ORNL/TM-7105. The WRITE statements are in the subroutines OUTPUT (in the DO loop ending with the statement number 95) and RISK (statements numbered 36 through 40).

[b]AIRDOS-EPA is documented in ORNL-5532. The outp... for DARTAB is produced by the subroutine DOSN in lines 3820, 3835, and 3858.

DTABLE, RTABLE, and FTABLE all indicate which tables are to be output for dose rates, health risks, and risk equivalents. They are each dimensioned by 7, for each of the possible tables (Table 1). The value of each position indicates the type of tables also:

TABLE(I) = 0 none of this type of table are to be output,
1 output the table for an individual,
2 output the table for a mean individual,
3 output the table for the collective group,
4 output all three types of the above table.

(Default: DTABLE,FTABLE: 0,0,0,0,0,0,0,RTABLE: 0,0,0,0,0,4,0)

OUTPUT is a logical variable which governs whether the dose factors will be output. (Default: .TRUE.)

GSCFAC is a ground surface correction factor. All ground surface quantities are multiplied by this factor to account for surface roughness.

3. Variables: ORGN,NORGN,TIME

Format: Namelist ORGAN

NORGN is the number of organs to be considered in the dose rate tables. (Default: 0)

ORGN are the alphanumeric names (double word - 8 characters) of the NORGN organs. (Default: Blank)

TIME is the time (years) associated with the dose commitment factor. (Default: 70 year dose commitment)

4. Variables: HLET,LLET

Format: Namelist QFACTOR

HLET is the relative biological effect factor to use for the high-LET dose rates to convert absorbed dose to dose equivalent (rem). (Default: 20)

LLET is the relative biological effect factor to use for the low-LET dose rates to convert absorbed dose to dose equivalent (rem). (Default: 1)

5. Variables: CANC,NCANC,RELABS

Format: Namelist CANCER

NCANC is the number of cancers to be output for the risk and risk equivalent factors. (Default: 1)

CANC are the alphanumeric names (double word length) of the NCANC cancers. (Default: W BODY)

RELABS indicates whether the absolute (=1) or relative (=2) risk model is to be used for each cancer. (Default: 1)

6. Variables: GENEFF,GEN,NGEN,GRFAC,REPPER,GLLET,GHLET

Format: Namelist GENTIC

GENEFF is a logical variable which indicates whether or not genetic effects are to be output.

GEN are the alphanumeric names (double word length) of the organs to be considered for genetic effects.

NGEN is the number of organs identified in GEN.

GRFAC are the risk conversion factors (genetic effects per rad/million births). GRFAC(1) is for low-LET doses; GRFAC(2) is for high-LET doses.

REPPER is the replacement rate for the population (year ^{1}). (Default: 0.014133)

GLLET is the relative biological effect factor to use for the low-LET genetic doses to convert absorbed dose to dose equivalents (rem), NGEN values for the GEN organs.

GHLET is the relative biological effect factor to use for the high-LET genetic doses to convert absorbed dose to dose equivalents (rem), NGEN values for the GEN organs.

7. Variables: NUCLID,NONCLD,PSIZE,RESP,GIABS

Format: Namelist RNUCLD

NONCLD is the number of radionuclides to be considered.

NUCLID are the alphanumeric names (double word) of the NONCLD radionuclides.

PSIZE is the activity median aerodynamic diameter (AMAB) of aerosol distribution associated with each radionuclide.

RESP is the respiratory clearance class associated with each radionuclide.

GIABS are the GI absorption factors (f_1 parameter for each segment of the gastrointestinal tract to be associated with each radionuclide.

8. Variables: NTLOC,RNLOC,OGLOC,PTLOC,FALOC,HLLOC,LTABLE

   Format: Namelist LOCTAB

NTLOC is the number of location tables to be output. (≤10). For each table, the following factors need to be defined.

RNLOC is the radionuclide to use; specifying SUM will result in the sum of all nuclides in the run, specifying WORKLEVL will result in working level calculations, specifying WLSUM will result in the total risk for all nuclides, including those based on the working level.

OGLOC is the organ or cancer to use, specifying SUM will result in the sum of all cancers (weighted sum for organ).

PTLOC is the pathway to use.

FALOC is the factor to be printed, i.e.,
HLLOC = 0 both high- and low-LET table,
HLLOC = 1 only combined LET table,
HLLOC = 2 all three tables.

LTABLE indicates whether the table is for the selected individual (LTABLE=1), mean individual (LTABLE=2), or the collective group (LTABLE=3).

9. Variables: NORGB,ORGB,ORGDAT,IPATH

   Format: Namelist ORGAN F

NORGB is the number of organ dose weights to use to combine dose rates.

ORGB are the NORGB organs to be used in combining the dose rates.

ORGDAT are the organ dose weighting factors.

IPATH is the exposure pathway affected (1 = ingestion; 2 = inhalation; 3 = air immersion; 4 = ground surface; 5 = all pathways).

3.4 Input Required for Dose Rates, Health Risks, and Risk Equivalent Factors

The dose and risk factor data are contained in the unformatted file read from unit 25. The records are grouped in blocks. The first record of the block contains the nuclide identifier for the block; the remaining records contain the dose and risk factor data.

Record 1

Variable list:

NUC,SIZEIN,RESPIN,GIIN,TIMIN,IND

Variable	Type	Description
NUC	REAL*8	8-character nuclide name
SIZEIN	REAL*4	AMAD (μm) for particulates. Particle size (AMAD) in μm for inhaled particles. Set to 0. if not used.
RESPIN	REAL*4	Lung clearance class (Y,W,D) for inhaled particles. Gases indicated by *. Blank if not used.
GIIN	REAL*4	4 value array for GI absorption factors for stomach, small intestine, upper large intestine, and lower large intestine, dimensionless. Only GIIN(2) is used for matching.
TIMIN	REAL*4	Age of which intake dose rate factor is calculated. Set to 0. for external dose rate factors and to 110.0 for risk factors.

IND indicator variable for record type in the block. Table 15 lists the possible values of IND. Note that values 0 and 1 are for exposure/intake records rather than dose or risk factors.

Record 2 dosimetric factors

Variable list: NO,ILET,(O(I),I=1,NO)

NO	INTEGER*4	Number of organs for which names and factors are included
INLET	INTEGER*4	INLET = 1 If only low-LET factors are included, ILET = 2 if both low- and high-LET factors are included
O	REAL*8	8-character alphanumeric organ or tissue names

Table 15. Possible values of indicator variable

Indicator variable	Information which follows
0	Individual concentrations and rates from AIRDOS
1	Population concentrations and rates from AIRDOS
2	Ingestion dose conversion factors
3	Inhalation dose conversion factors
4	Air immersion dose conversion factors
5	Ground surface dose conversion factors
12	Absolute health risk, years of life loss, and risk equivalent conversion factors for cancers due to ingestion
13	Absolute health risk, years of life loss, and risk equivalent conversion factors for cancers due to inhalation
22	Relative health risk, years of life loss, and risk equivalent conversion factors for cancers due to ingestion
23	Relative health risk, years of life loss, and risk equivalent conversion factors for cancers due to inhalation
14	Absolute health risk, years of life loss, and risk equivalent conversion factors for cancers due to air immersion
15	Absolute health risk, years of life loss, and risk equivalent conversion factors for cancers due to ground surface exposure
24	Relative health risk, years of life loss, and risk equivalent conversion factors for cancers due to air immersion
25	Relative health risk, years of life loss, and risk equivalent conversion factors for cancers due to ground surface exposure
33	Relative health risk, years of life loss, and risk equivalent conversion factors in terms of working levels for Rn-222
96	Genetic dose conversion factors for ground surface exposures
97	Genetic dose conversion factors for air immersion
98	Genetic dose conversion factors for inhalation
99	Genetic dose conversion factors for ingestion

Record 2 risk factors

Variable list: NC, ILET, (C(I),I=1,NC)

NC	INTEGER*4	Number of cancers for which k factors are listed
ILET	INTEGER*4	ILET
C	REAL*8	8 character alphanumeric cancer names

Record 3 dose rate and genetic dose factors

Variable list: ((D(I,J),I=1,ILET), J=1,NO)

D	REAL*4	IND	UNIT
		2	rad/pCi
		3	rad/pCi
		4	(rad/yr)/(μCi/cc)
		5	(rad/yr)/(μCi/cm^2)
		96	rad/(pCi/cm^2)
		97	rad/(μCi/cc)
		98	rad/(pCi/yr)
		99	rad/(pCi/yr)

The dose factor D(I,J) is for the organ or tissue O(J).

Record 3 risk factors

Variable list: ((R(I,J), I = 1, ILET), J = 1,NC)

R	REAL*4	IND	UNIT
		12,22	Effects/(10^5 person·pCi/yr)
		13,23	Effects/(10^5 person·pCi/yr)
		14,24	Effects/(10^5 person·pCi/cc)
		15,25	Effects/(10^5 person·pCi/cm^2)
		33	Effects/(person·WL)

Record 4 risk factors

Variable list: ((YRLL(I,J),I=1,ILET),J=1,NC)

Total life loss factor

YRLL	REAL*4	IND	UNITS
		12,22	yr/(10^5 person·pCi/yr)
		13,23	yr/(10^5 person·pCi/yr)
		14,24	yr/(10^5 person·pCi/cc)
		15,25	yr/(10^5 person·pCi/cm^2)
		33	yr/(person·WL)

Record 5 risk factors

Variable list: (RF(J), J=1,NC+1) risk equivalent factor

RF	REAL*4	IND	UNITS
		12,22	mrem/(pCi/yr)
		13,23	mrem/(pCi/yr)
		14,24	mrem/(pCi/cc)
		15,25	mrem/(pCi/cm^2)
		33	(mrem/yr)/WL

RF(NC+1) is the whole body risk equivalent factor.

3.5 Input Required for Exposures

There are four types of records required for the radionuclide exposure data. The data are unformatted and are read from unit 26.

Record 1

Variables: NUC,SIZEIN,RESPIN,GIIN,TIMIN,IND

The first record is exactly comparable to the first record required for dose rate, health risk, and risk equivalent factors, except that GIIN(1) is the GI absorption value for inhalation, GIIN(2) is the value for ingestion, and GIIN(3) and GIIN(4) equal zero.

Record 2

Variables: NOL,NOU,NRL,NRU,(IDIST(I),I=NRL,NRU)

NOL is lower bound of the direction index considered in the assessment.

NOL = 1 indicates NORTH and increases counterclockwise to 16 = NNE.

NOU is the upper bound of the direction index.

NRL is the lower bound of the distance index considered in the assessment.

NRU is the upper bound of the distance index.

IDIST are distances from the source in meters for indices NRL to NRU.

Record 3

Variable: (CONC(I),I=1,II)

CONC are radionuclide exposure values for air concentration, surface concentration, ingestion and inhalation for a specific location. This record is repeated for each location in the type assessment.

II=4 unless NUC = Rn-222 for which II=2.

For NUC ≠ Rn-222

CONC(1)	REAL*4	Air concentration (Ci/cm^3)
CONC(2)	REAL*4	Ground surface concentration (Ci/cm^2)
CONC(3)	REAL*4	Collective ingestion rate (pCi·person/yr)
CONC(4)	REAL*4	Collective inhalation rate (person·pCi/yr)

For NUC = Rn-222

CONC(1)	REAL*4	Fraction of equilibrium
CONC(2)	REAL*4	Radon daughter CONC(person·WL)

There are k=(NRU+1-NRL)*(NOU+1-NOL) records of type 3 for each record group.

Record 4

Variable: ((POP(I,J),I=NRL,NRM),J=NOL,NOU)

POP (REAL*4) are number of persons at each location. This record is not written for IND=0 (individual assessment).

The input stream for the example tables is given in Table 14. Additional listings can be found in the attached microfiche.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the untiring efforts of Christopher B. Nelson, Project Officer for the U.S. Environmental Protection Agency, Office of Radiation Programs. Without his detailed guidance, the project would not have so exactly addressed the agency's needs. Others at the Oak Ridge National Laboratory who have contributed to the development of this project are C. F. Baes III, whose patient efforts have contributed to keeping the multidisciplinary, multiorganizational working group together; and Wilma Minor who patiently edited and typed this manuscript for each of its many versions.

REFERENCES

Cook, J. R., B. M. Bunger, and M. K. Barrick. 1978. *A Computer Code for Cohort Analysis of Increased Risks of Death (CAIRD)*, EPA 520/4-78-012.

Dunning, D. E. Jr., R. W. Leggett, and M. G. Yalcintas. 1980. *A Combined Methodology for Estimating Dose Rates and Health Effects from Radioactive Pollutants*. ORNL/TM-7105.

International Commission on Radiological Protection. 1979. "Limits for Intakes of Radionuclides by Workers." *ICRP Publication 30, Part 1, Annals of the ICRP*, Vol. 3, No. 4. Pergamon Press.

International Mathematical and Statistical Libraries, Inc. 1977. *IMSL Library Reference Manual*, Vols. I and II. Report IMSL LIBl-0006 revised. Available from IMSL Sixth Floor, GNB Building, 7500 Bellaire Building, Houston, Texas 77036.

Kocher, D. C. 1979. *Dose Rate Conversion Factors for External Exposure to Photon and Electron Radiation from Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities*. ORNL/NUREG/TM-283.

Moore, R. E., C. F. Baes III, L. M. McDowell-Boyer, A. P. Watson, F. O. Hoffman, J. C. Pleasant, and C. W. Miller. 1979. *AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides*. ORNL-5532.

National Academy of Sciences — National Research Council. 1972. *The Effects on Population of Exposure to Low Levels of Ionizing Radiation*. Report of the Committee on the Biological Effects of Ionizing Radiations (BEIR I), Washington, D. C.