

ADVANCED TURBO FRMAC



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OUTLINE

- Advanced Inputs and Calculations – Public Protection
- Advanced Do It Yourself Calculations – Public Protection
- Advanced Inputs and Calculations – Ingestion
- Advanced Do It Yourself Calculations – Ingestion
- Final Exercise

Time permitting:

*Revising the Source Term

*Pitfalls in Dose Assessment



***ADVANCED PUBLIC
PROTECTION INPUTS
AND CALCULATIONS***



OTHER INPUTS FOR DRL CALCULATIONS

Additional, detailed inputs for the DRL Calculation

Populated with default values, and do not **need** to be altered to run a calculation

A thorough understanding of the inputs is recommended before the user changes values from the defaults





OTHER INPUTS – BREATHING RATES

- Default Assumptions
 - Early Phase – Adult Male Light Exercise Breathing Rate
 - All other Phases – Adult Male Activity Averaged Breathing Rate
- Changing the Breathing Rate
 - Questions may arise about specific populations or protective actions where a higher breathing rate may better fit the scenario

Breathing Rates Help

Select Gender: Male ICRP Guidance: ICRP 60

Inputs

Activity Time: Indicates a valid summation of 24 hours

Activity	3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
Sleeping	17.0	14.0	12.0	10.0	10.0	8.5
Sitting	N/A	3.33	4.0	4.67	5.5	5.5
Light Exercise	7.0	6.67	8.0	9.33	7.5	9.75
Heavy Exercise	N/A	N/A	N/A	N/A	1.0	0.25

24.0 hrs 24.0 hrs 24.0 hrs 24.0 hrs 24.0 hrs 24.0 hrs

Activity Time Units: hr
[0.0, 24.0]

Breathing Rates:

Activity	3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
Sleeping	9.00E-2	0.15	0.24	0.31	0.42	0.45
Sitting	N/A	0.22	0.32	0.38	0.48	0.54
Light Exercise	0.19	0.35	0.57	1.12	1.38	1.5
Heavy Exercise	N/A	N/A	N/A	N/A	2.92	3.0

Breathing Rate Units: m³ / hr
(0.0, 36.0]

Results

Activity-Averaged Breathing Rates: Auto Calculate

3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
0.12	0.22	0.36	0.64	0.84	0.92

Activity-Averaged Breathing Rate Units: m³ / hr
(0.0, 36.0]



OTHER INPUTS – ICRP AND LUNG CLEARANCE

Default to ICRP
Recommended Clearance
Type – Differs from NRC
assumption

Each radionuclide can be
changed independently

Tied to Required ICRP Panel

- For ICRP 30 runs, inhalation coefficient bases option is removed.
- ICRP 30 runs still default to ICRP Recommended Clearance Type. This must be changed manually to reflect the Maximum clearance type still used by NRC

ICRP and Lung Clearance

Lung Clearance Options

Master Particulate Lung Clearance Type: ICRP Recommended

Override the Lung Clearance Type of individual radionuclides rather than using the Master Lung Clearance Type

Radionuclide Form

Day (D)
Week (W)
Year (Y)
Gas
Maximum
ICRP Recommended

If a radionuclide does not have Lung Clearance Type values for the chosen Lung Clearance Type, then the values for the Maximum Lung Clearance Type will be used.

Reset to Master Lung Clearance Type...

0 parents, 0 daughters, 0 total

Indicates the Lung Clearance Type for the radionuclide supercedes the Master Lung Clearance Type.



OTHER INPUTS – INSTRUMENT THRESHOLDS AND KI PROTECTION FACTORS

Given information on the detector used for a scenario, the user can change the energy threshold for detection

Public Protection DRL calculations can consider the administration of KI

- For purely KI DRLs, the user should leverage the Administration of KI calculation

Instrument Thresholds

Define the minimum threshold value that the radiation detection instrument is capable of detecting.

Instrument Beta Energy Threshold: keV
[0.0, 5.12E2]

KI Protection Factors

Configure Potassium Iodide (KI) Administered Settings for Each Time Phase

All Time Phases

Administered Potassium Iodide (KI) for Plume Inhalation

[1.0, 1.00E5]

Administered Potassium Iodide (KI) for Resuspension Inhalation

[1.0, 1.00E5]



OTHER INPUTS – RESUSPENSION AND WEATHERING CORRECTIONS

Resuspension can vary with terrain, weather, and time

User can edit all coefficients to account for changing weathering and resuspension variables through the course of an incident

Resuspension Help

Configure Resuspension Settings for Each Time Phase

All Time Phases

Calculation Method: User Defined

Time Varying Coefficients

Coefficient #1:	<input type="text" value="1.00E-5"/>	<input type="text" value="m<sup>-1</sup>"/>
	[0.0, 1.0]	
Coefficient #2:	<input type="text" value="7.00E-9"/>	<input type="text" value="m<sup>-1</sup>"/>
	[0.0, 1.0]	
Coefficient #3:	<input type="text" value="1.00E-9"/>	<input type="text" value="m<sup>-1</sup>"/>
	[0.0, 1.0]	
Exponent Coefficient #1:	<input type="text" value="8.10E-7"/>	<input type="text" value="s<sup>-1</sup>"/>
	[1.00E-20, 1.0]	
Exponent Coefficient #2:	<input type="text" value="2.31E-8"/>	<input type="text" value="s<sup>-1</sup>"/>
	[1.00E-20, 1.0]	

Weathering Correction Help

Configure Weathering Correction Settings for Each Time Phase

All Time Phases

Weathering Correction: Enabled

Weathering Coefficients:

Coefficient #1:	<input type="text" value="0.4"/>	
	[0.0, 1.0]	
Coefficient #2:	<input type="text" value="0.6"/>	
	[0.0, 1.0]	
Exponent Coefficient #1:	<input type="text" value="1.46E-8"/>	<input type="text" value="s<sup>-1</sup>"/>
	[1.00E-20, 1.0]	
Exponent Coefficient #2:	<input type="text" value="4.44E-10"/>	<input type="text" value="s<sup>-1</sup>"/>
	[1.00E-20, 1.0]	



OTHER INPUTS – PLUME AND RESUSPENSION PARTICLE SIZE DISTRIBUTIONS

Default assumption is 100% monodispersed 1 micron AMAD particulate

User can change particle size based on mass median diameter or mass median aerodynamic diameter for all or a fraction of the material

Important for lung dose calculations as changing the particle size changes the inhalation dose coefficient

Particle Size Distribution

Edit Monodispersed Particle Size Distribution
Edit the properties of the Monodispersed Particle Size Distribution.

Enter the Monodispersed Particle Size Distribution properties.

Known Particle Diameter

Mass Median Diameter (MMD): 1.0 micron [1.00E-4, 1.00E4]

Mass Median Aerodynamic Diameter (MMAD): 1.0 micron [1.00E-3, 1.00E4]

Specific Gravity
The Specific Gravity value cannot be edited here, but it is used to calculate the Unknown Particle Diameter.

Specific Gravity: User Defined
1.0

Fraction of Material
Fraction of Material: 1.0 Fraction (0.0, 1.0]

OK Cancel



SCENARIO SPECIFIC PSDS

Pre-assessed scenarios with specific PSDs will have the specific PSDs loaded in with the mixture in Mixture Manager

Import Radionuclide Mixture Wizard

Import Radionuclide Mixture

Import a mixture from Radionuclide Mixture Manager.

Choose Mixture to Import

Select Mixture

- Criticality Accident
- Nuclear Detonation
 - HEU Weapon Detonation Mixture
 - WGPu Weapon Detonation Mixture
- Nuclear Power Plant
- Nuclear Power Plant Coolant
- Nuclear Power Plant Monitored Mixture
- Other
- Plutonium
- Spent Nuclear Fuel
- Uranium

HEU Weapon Detonation Mixture, 1 h post-detonation

Name: HEU Weapon Detonation Mixture, 1 h post-detonation

Description: Top dose contributors deposited 10 km downwind at 1 hour post-detonation for ground burst detonation of a highly enriched uranium (HEU) weapon

Form	Radionuclide	Activity per Area	Integrated Air Concentration	Deposition Velocity	Plume Particle Size Distribution
P	^{140}Ba	4.79E2	7.36E2	0.65	Log 80%, Log 20%
P	^{141}Ba	4.88E4	1.81E5	0.27	Log 80%, Log 20%
P	^{142}Ba	1.50E4	1.15E5	0.13	Log 80%, Log 20%
P	^{141}Ce	18.6	15.0	1.24	Log 80%, Log 20%
P	^{143}Ce	3.92E3	5.30E3	0.74	Log 80%, Log 20%
P	^{144}Ce	18.8	28.8	0.65	Log 80%, Log 20%
P	^{58}Co	4.36	6.52	0.67	Log 80%, Log 20%
P	$^{58\text{m}}\text{Co}$	7.00E2	1.11E3	0.63	Log 80%, Log 20%
P	^{134}Cs	6.58E-3	9.55E-3	0.69	Log 80%, Log 20%
P	$^{134\text{m}}\text{Cs}$	26.6	44.8	0.59	Log 80%, Log 20%
P	^{137}Cs	0.58	0.89	0.65	Log 80%, Log 20%

50 parents, 85 daughters, 135 total radionuclides, 195 total forms

Truncation: ON Equilibrium: OFF

$\mu\text{Ci} / \text{m}^2$ ($\mu\text{Ci} \cdot \text{s} / \text{m}^3$) m / s

Indicates a custom Particle Size Distribution for a Radionuclide

More Properties

Cancel Reset Back Next Finish

Use the Back, Next, and Finish buttons to continue. You need to complete each Step in the order specified.



HOW TO READ THE PSD TABLE

These are **NOT** actual PSD distributions!

RDD Nuclide	Form	Distribution	Respirable Particles	Medium Particles	Large Particles	Fragments
			Lognormal MMAD = 2 GSD = 2 Min: 0.25 μm Max: 10 μm	Uniform Min: 10 μm Max: 100 μm	Uniform Min: 100 μm Max: 500 μm	Uniform Min: 500 μm Max: 2000 μm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Created: This is the particle size distribution created by the blast. Large Particles and Fragments are not expected to be transported atmospherically and are deposited in the immediate blast area. Therefore, for downwind assessments, the source term should be scaled to exclude the Large Particles and Fragments to calculate the amount of material that will be aerosolized and dispersed downwind.

Aerosolized: This is the distribution that should be used to calculate the DRLs based on the scaled source term, which excludes the larger particles that are not deposited outside the immediate blast area.



CREATED FRACTIONS

RDD Nuclide	Form	Distribution	Respirable Particles	Medium Particles	Large Particles	Fragments
			Lognormal MMAD = 2 GSD = 2 Min: 0.25 μm Max: 10 μm	Uniform Min: 10 μm Max: 100 μm	Uniform Min: 100 μm Max: 500 μm	Uniform Min: 500 μm Max: 2000 μm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Source Term: Suppose 1000 Ci of Ag-111 and 500 Ci of Au-198 were detonated in an RDD.

The “Created” rows tell us that for dose assessment purposes we should use a source term of:

400 Ci of Ag-111 $[(0.2+0.2)*1000]$ and
200 Ci of Au-198 $[(0.3+0.1)*500]$



AEROSOLIZED FRACTIONS

RDD Nuclide	Form	Distribution	Respirable Particles	Medium Particles	Large Particles	Fragments
			Lognormal MMAD = 2 GSD = 2 Min: 0.25 μm Max: 10 μm	Uniform Min: 10 μm Max: 100 μm	Uniform Min: 100 μm Max: 500 μm	Uniform Min: 500 μm Max: 2000 μm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Source Term: Suppose Ag-111 and Au-198 were detonated in an RDD

The “Aerosolized” rows tell us that for dose assessment purposes we should use PSDs of:

50% Respirable and 50% Medium for Ag-111 and
75% Respirable and 25% Medium for Au-198



CUSTOM PSD IN TURBO FRMAC

Can be entered in two places!

First is the “Master” PSD. This sets the PSD for all radionuclides in your mixture

Select *Plume or Resuspension Particle Size Distribution*

Derived Response Levels | show all inputs (both Required and Other) that can impact the calculations.

Plume Particle Size Distribution

Row	Distribution	Min Aerodynamic Diameter	Max Aerodynamic Diameter	Fraction of Material
1	Monodispersed	1.0	1.0	1.0

Total: (0.0, 1.0)

Specific Gravity: User Defined
1.0
[1.000E-2, 100.0]

Resuspension Particle Size Distribution

Row	Distribution	Min Aerodynamic Diameter	Max Aerodynamic Diameter	Fraction of Material
1	Monodispersed	1.0	1.0	1.0

Total: (0.0, 1.0)

Specific Gravity: User Defined
1.0
[1.000E-2, 100.0]

Resuspension

Configure Resuspension Settings for Each Time Phase

All Time Phases

Calculation Method: Time Varying | Maxwell/Anspaugh's Method
 User Defined

Time Varying Coefficients



CUSTOM PSD IN TURBO FRMAC

Can be entered in two places!

Second is the radionuclide-specific PSD in the Mixture panel. Enter your mixture first!

Derived Response Levels | Review and edit the most commonly used inputs for the calculations.

Radionuclide Mixture

Name: Cs-137
Description:

Mixture and Measurement Type
 Generic Activity per Area Mass per Area

What Values are Known for the Mixture?
 Activity per Area *Integrated Air Concentration values will be calculated using the Deposition Velocity.*
 Integrated Air Concentration
 Both

Add Radionuclide: Search... Import Export & Email Manage Daughters Age Scale View 2015 ICRP 60

Form	Radionuclide	Activity per Area	Integrated Air Concentration	Deposition Velocity	Plume Particle Size Distribution	Resuspension Particle Size Distribution
<input type="checkbox"/> P	137Cs	0.0	0.0	3.00E-3	Mono 100%	Mono 100%
	137mBa	0.0	0.0	3.00E-3	Mono 100%	Mono 100%



OTHER INPUTS – BUILDING PROTECTION FACTORS AND EXPOSURE TO DOSE CONVERSION FACTORS

Building protection factors allow users to determine the dose reduction based on sheltering

Works hand in hand with occupancy factors

Exposure to Dose Conversion Factors are used to convert a Self Reading Dosimeter reading to a total dose

Building Protection Factors Help

Building Protection Factors will have no effect on Groundshine or Resuspension Inhalation for Time Phases where the Inside Occupancy Factor is Zero.

User Defined Plume Submersion and Groundshine Factors

Building Types:

One and Two-Story Single-Family Residential Building

Heavy Construction Building

Basement Types:

Above Basement

Basement

Plume Inhalation:
(0.0, 1.00E3]

Plume Submersion:
(0.0, 1.00E3]

Resuspension Inhalation:
(0.0, 1.00E3]

Groundshine:
(0.0, 1.00E3]

Exposure to Dose Factors Help

Time Phase	Exposure to Dose Conversion Factor
Early Phase (TD)	1.0
Early Phase (AD)	1.0
First Year	1.0
Second Year	1.0
Fifty Year	1.0

mrem / mR
[0.0, 10.01]

Ground Roughness Factor:
[0.0, 1.0]



OTHER INPUTS - BUILDING PROTECTION FACTORS (BPF)

FRMAC Assessment Manual, Appendix C, Table 6-1
 Default Building Protection Factors for Public Protection Decisions

Building Type	Cloud Submersion Protection Factor	Deposition Protection Factor
One- and two- story single-family residential building ¹		
Above Basement	1.5	2.5
Basement	3	10
Heavy Construction Building ^{2,3,4}		
Above Basement	5 ³	50 ⁴
Basement	5 ³	600 ⁴
¹ Dixon & Hamby, Journal of Radiological Protection, 2016. ² Buildings constructed from brick or concrete with relatively thick (0.2 to 1+ m) walls and roofs and large, both in height and footprint. May include large multi-family (e.g., apartment), office and industrial buildings. ³ Cloud Submersion - Protective Action Evaluation Part 1, EPA 520/1-78-001A ⁴ Deposition - Dillon, et.al, LLNL-TR-684121		

NOTE: Default BPFs are only provided for external exposure pathways. Defaults for the inhalation pathway have not been determined and are assumed to be 1



OTHER INPUTS - OCCUPANCY FACTORS

Public Protection methods assume the receptor is outside in the Contaminated Area continuously without protection during the Time Phase

More realistic – some form of shelter and/or some time spent outside of the contaminated area

FRMAC Assessment Manual Method 4.7

Occupancy Factors Help

Configure Occupancy Factors for Individual Time Phases

All Time Phases

Occupancy Factors have no effect on Plume Pathway calculations. If plume dose pathways are included, the receptor is assumed to be exposed to the entire plume.

Occupancy Factors: Enabled

How do you wish to provide Occupancy Factors?

Calculate Occupancy Factors Enter Occupancy Factors Manually

Calculation Inputs

Calculator Tool Coefficients: Default Coefficients ▾

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone	
Days/Week	7	0	[0, 7]
Hours/Day Absent	0.0	0.0	
Hours/Day Sheltered	0.0	0.0	
Hours/Day Unsheltered	24.0	24.0	
	[0.0, 24.0]	[0.0, 24.0]	

Occupancy Factors

Inside Occupancy Factor: 0.0 Fraction ▾
[0.0, 1.0]

Outside Occupancy Factor: 1.0 Fraction ▾
[0.0, 1.0]



OTHER INPUTS – OCCUPANCY FACTORS

Primarily intended to determine potentially more realistic values for 1st & 2nd year Relocation DRLs, but can be applied any Time Phase

Can also be used to determine potential dose to individuals living outside a contaminated area and working inside

Occupancy Factors consider that, at different portions of the Time Phase, receptors may be:

- outdoors, unsheltered in the contaminated area
- sheltered inside a structure in the contaminated area
- absent from the contaminated area



OCCUPANCY FACTORS

OF_{out} = Outside Occupancy Factor, the fraction of the Time Phase spent outdoors in the contaminated area, unitless;

OF_{in} = Inside Occupancy Factor, the fraction of the Time Phase spent inside a building in the contaminated area, unitless;

NOTE: These Occupancy Factors will not sum to one (1) if the receptor is absent from the contaminated area during any part of the Time Phase under consideration.



MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Remember: Dose Parameters are integrated quantities calculating the dose over a certain time from a specific pathway. Which are then used to calculate applicable DRLs

In these examples, we will be considering the Deposition External Dose Parameter (Dp_ExDP), which represents the integrated External Dose from a deposited mixture over the Time Phase of interest.



MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Modifying Dp_ExDP for Sheltering Only:

Divide the default Dose Parameter by the Building Protection Factor (BPF) giving the Sheltered External Dose Parameter for the radionuclide, the Time Phase and the specific BPF

$$Dp_ExDP_{i,TP,sh} = \frac{Dp_ExDP_{i,TP}}{BPF_{Dp,Ex}}$$

$$mrem = \frac{mrem}{unitless}$$

where:

$BPF_{Dp,Ex}$ = Building Protection Factor for Deposition External Exposure, a factor to account for the reduction in External Dose due to being inside a building, unitless



MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Modifying Dp_ExDP for Occupancy and Sheltering

The Inside Occupancy Factor is divided by the BPF and then summed with the Outside Occupancy Factor

$$Dp_ExDP_{i,TP,Sh} = Dp_ExDP_{i,TP} * \left(OF_{out} + \frac{OF_{In}}{BPF_{Dp,Ex}} \right)$$

$$mrem = mrem * \left(unitless + \frac{unitless}{unitless} \right)$$

where:

OF_{out} = Outside Occupancy Factor, fraction of Time Phase spent outside in a contaminated area, unitless;

OF_{in} = Inside Occupancy Factor, fraction of Time Phase spent sheltered in a contaminated area, unitless;

NOTE: These Occupancy Factors will not sum to one (1) if the receptor is absent from the contaminated area during any part of the Time Phase under consideration.

$BPF_{Dp,Ex}$ = Building Protection Factor for Deposition External Exposure, a factor to account for the reduction in External Dose due to being inside a building, unitless



MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Example:

Assuming a ground concentration of $2 \mu\text{Ci}/\text{m}^2$ of Co-60, modify the 1st Yr Dp_ExDP (379 mrem) by including the effects of Occupancy and Sheltering

Assuming the receptor is:

- unsheltered (outdoors) in the contaminated area for 6 hours/day ($OF_{Out} = 0.25$)
- sheltered in a building in the contaminated area for 9 hours/day ($OF_{In} = 0.375$)
- absent from the contamination area for 9 hours/day

NOTE: The Occupancy Factors will not sum to 1 if the receptor is absent from the contaminated area during any part of the Time Phase.

The building has a Building Protection Factor for Deposition External Exposure of 2.5

$$Dp_ExDP_{i,TP,Sh} = 379 \text{ mrem} * \left(0.25 + \frac{0.375}{2.5} \right)$$

$$Dp_ExDP_{Co-60, 1st Year, Sh} = 152 \text{ mrem}$$



***PUBLIC PROTECTION
DO IT YOURSELF
PRACTICE***



OCCUPANCY AND SHELTERING EXAMPLE

Please take out your laptops to walk through the following examples with us.





SETTING THE STAGE

We have a request:

The Governor would like to know how applying Occupancy and Sheltering to the 1st Year DRL would change his potential order to relocate his downwind population.

Use the default 1st Year Time Phase with an Evaluation Time of 7 days

Assume the following Mixture

Radionuclide	Activity per Area ($\mu\text{Ci}/\text{m}^2$)
^{60}Co	2
^{148}Gd	1
^{90}Sr	3
$^{90}\text{Y}^a$	3
^a ^{90}Y included as a daughter in equilibrium	



SETTING THE STAGE

We will make the following assumptions regarding Occupancy and Sheltering:

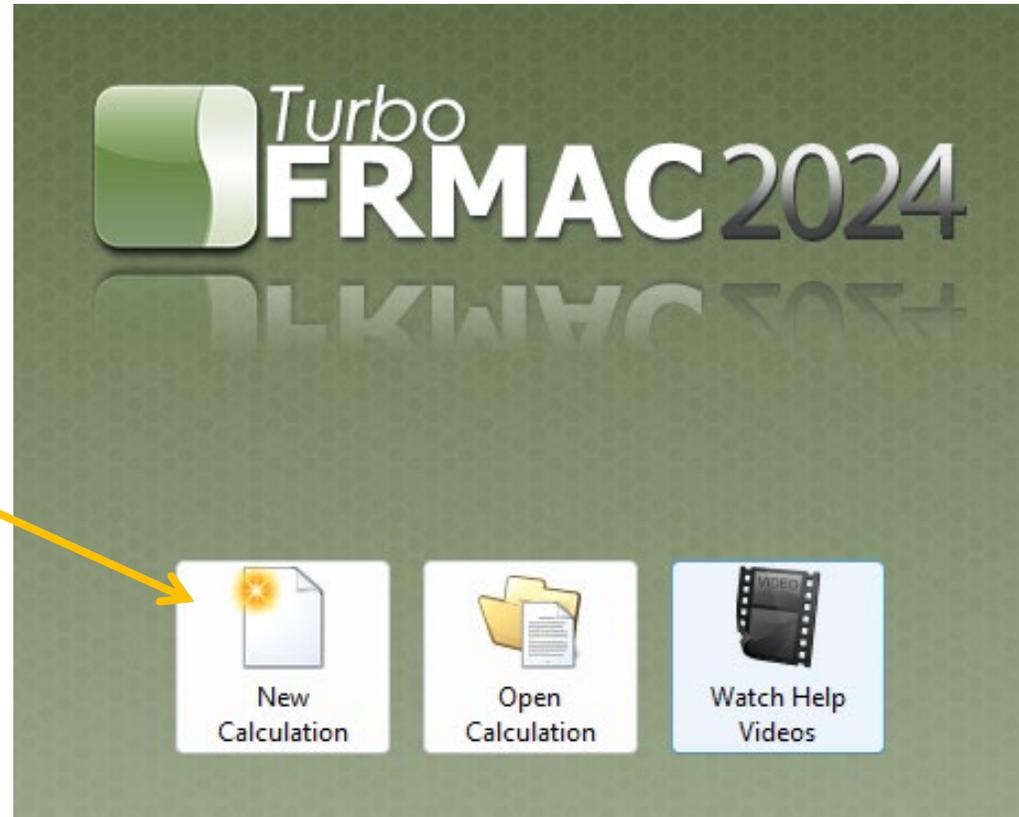
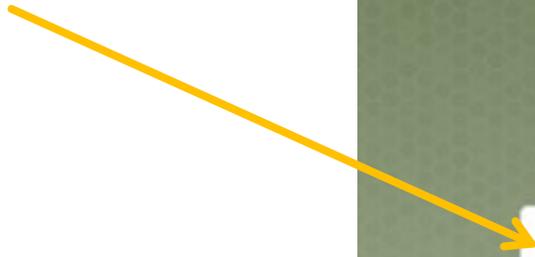
- An individual lives inside the contaminated area
- They work 5 days a week for 10 hrs/day (commute and work) outside the contaminated area
- They spend 12 hrs/day sheltered
- Their home is a 1-story residential building (deposition protection factor of 2.5)

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone
Days/Week	2	5
Hours/Day Absent	0	10
Hours/Day Sheltered	12	12



OPEN TURBO FRMAC

Select New Calculation





SELECT NEW CALCULATION

Start Your Calculation | Choose the type of Calculation you wish to perform.

1 Browse Categories

- Public Protection**
Evaluate the potential impacts to members of the public from exposure to radiological materials in the air and/or deposited on the ground.
- Worker Protection**
Establish worker protection guidelines (e.g., turn-back limits and derived response levels).
- Ingestion**
Evaluate the potential impacts from radiologically contaminated food.
- Supplemental**
Perform additional calculations to support radiological assessments.

2 Select Calculation

- Derived Response Levels**
Calculate the areal or integrated air activity of radionuclides at which the total dose from the mixture equals the PAG over the time phase.
- Administration of KI DRL**
Calculate the areal or integrated air activity of radionuclides to support decisions to administer Potassium Iodide in response to releases of iodine radionuclides.
- Projected Public Dose**
Calculate the dose from exposure to a release of radioactive material.
- Dose Parameters**
Calculate the External, Inhalation, and Total Dose Parameters.

3 Choose Template

- Blank**
Create a Calculation using all default inputs.
- Copy from Existing**
Make a copy of a saved Calculation to get started.

Select Public Protection, then Derived Response Level, then Blank



VERIFY TIME PHASES AND EVALUATION TIME

- Click on Time Settings Button
- Delete all but First Year Time Phase
- Change Evaluation Time to 7 days

Derived Response Levels | Show all inputs (both Required and Other) that can impact the calculations.

Show All Inputs

- Name and Description
- Time Settings**
- Radionuclide Mixture
- ICRP Guidance

Time Settings

Release Date & Time: 05/04/2021 10:01 CST/MDT (UTC-06:00)

Date/Time Mode: Date & Time Time After Release

+ Add - Delete... Reset

Time Phase	Start Time	Duration	End Time	Evaluation Time	Plume Inhalation	Plume Submersion	Resuspension Inhalation	Groundshine
First Year	12.0	8.76E3	8.77E3	7.00	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

hr hr hr d
[0.0, 8.77E5] [1.67E-2, 8.77E5] [0.0, 8.77E5]



BUILD RADIONUCLIDE MIXTURE

Click on Radionuclide Mixture Button

Search and Enter each Radionuclide in the mix and the Activity Concentration

Derived Response Levels | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Time Settings
- Radionuclide Mixture**
- ICRP Guidance
- Protective Action Guides (PAGs)

Radionuclide Mixture

Name: Public Protection

Description: 1st Year DRLs

Mixture and Measurement Type

Generic Activity per Area Mass per Area

Known Mixture Values
What values do you know for the Mixture?

Radionuclide	Activity per Area
⁶⁰ Co	2.00
¹⁴⁸ Gd	1.00
⁹⁰ Sr	3.00

Add Radionuclide:

co

Searching Search All Radionuclides

- Co-55
- Co-56
- Co-57
- Co-58
- Co-58m
- Co-60
- Co-60m
- Co-61
- Co-62m

0 parent

Forms: /m² (μCi · s)/m³ m/s

[-4.86E303, 4.86E303] [-4.86E303, 4.86E303] [-∞, ∞]

Daughters are assigned the Deposition Velocity of their parent.

The Mixture must contain 1 or more Radionuclides. Add Radionuclides or Import a Mixture.



RUN CALCULATION - DEFAULT

Click the Deposition button



The screenshot shows the software interface for "New Derived Response Levels Calculation - Turbo FRMAC". The "Deposition" button in the "Dose and Exposure" group is highlighted. A progress dialog box is open, showing the following progress:

Category	Progress
Overall	94%
Radionuclide Mixture	100%
Derived Response Levels	100%
Decay & Ingrowth Denominator Terms	100%

The dialog box also includes a "Cancel" button and an "Elapsed Time:" field.



DEPOSITION DRLS - DEFAULT

Final Results displayed

Derived Response Levels | View the calculated results for the Alpha, Beta, and Radionuclide-specific Deposition DRLs.

Deposition Results

- Alpha DRLs
- Beta DRLs
- Radionuclide-Specific DRLs**

Radionuclide-Specific DRLs

Whole Body values are displayed for Adult for a Chronic Commitment Period.

Radionuclide	Form	First Year
⁶⁰ Co	P	7.34
¹⁴⁸ Gd	P	3.68
⁹⁰ Sr	P	11.04
⁹⁰ Y	P	11.04

DRL Units: μCi / m^2



DOSE RATE DRL - DEFAULT

Final Results displayed

Derived Response Levels | View the calculated results for the Dose Rate and Exposure Rate DRLs.

Dose and Exposure Results

- Dose Rate DRLs
- Exposure Rate DRLs

Dose Rate

W... are displayed for **Adult** for a **Chronic** Commitment Period.

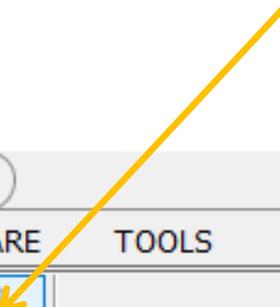
First Year	0.2
Fir	0.198

Dose Rate DRL Units: mrem / hr



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Click on Show All



The screenshot shows the software interface with the following elements:

- File Menu:** File, HOME, SHARE, TOOLS, HELP
- Inputs Section:**
 - Required, Other, **Show All** (highlighted)
 - 1992 EPA PAG Manual Emulation Mode (OFF)
 - Reset Inputs
- Results Section:**
 - Dose and Exposure (DRL)
 - Deposition (DRL)** (highlighted)
 - Integrated Air (DRL)
 - Dose Parameters (DP)
 - More Mixture Properties
 - Age Group: Adult
 - Organ: Whole Body
- Derived Results:**
 - Show All** tooltip: Show all inputs (both Required and Other) that can impact the calculations.
 - calculated results for the Alpha, Beta, and Radionuclide-specific Deposition DRLs.
 - Radionuclide-Specific DRLs



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Click on Building Protection Factors

There are two modes of entering the BPF; manually and via the default radio buttons.

To manually adjust the BPF, enter 2.5 for Groundshine

The screenshot displays the 'Building Protection Factors' configuration window. On the left, a vertical menu lists various settings, with 'Building Protection Factors' highlighted. The main window contains the following information:

- Building Protection Factors** (with an expand/collapse icon)
- Building Protection Factors will have no effect on Groundshine or Resuspension Inhalation for Time Phases where the Inside Occupancy Factor is Zero.
- User Defined Plume Submersion and Groundshine Factors**
- Building Types:**
 - One and Two-Story Single-Family Residential Building
 - Heavy Construction Building
- Basement Types:**
 - Above Basement
 - Basement
- Plume Inhalation:** 1.0 (0.0, 1.00E3]
- Plume Submersion:** 1.0 (0.0, 1.00E3]
- Resuspension Inhalation:** 1.0 (0.0, 1.00E3]
- Groundshine:** 2.5 (0.0, 1.00E3]



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

To adjust the BPF using the radio buttons, de-select the user defined box, and select “One and Two-Story Single-Family Residential Building” and “Above Basement”

Relative Biological Effectiveness

Breathing Rates

Building Protection Factors

Exposure to Dose Factors

ICRP and Lung Clearance

Instrument Thresholds

Building Protection Factors

Building Protection Factors will have no effect on Groundshine or Resuspension Inhalation for Time Phases where the Inside Occupancy Factor is Zero.

User Defined Plume Submersion and Groundshine Factors

Building Types:

- One and Two-Story Single-Family Residential Building
- Heavy Construction Building

Basement Types:

- Above Basement
- Basement

Plume Inhalation: 1.0
(0.0, 1.00E3]

Plume Submersion: 1.5
(0.0, 1.00E3]

Resuspension Inhalation: 1.0
(0.0, 1.00E3]

Groundshine: 2.5
(0.0, 1.00E3]

Notice that the Groundshine submersion factor is 2.5



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Click on Occupancy Factor

Derived Response Levels | Show all inputs (both Required and Other) that can impact the calculations.

Show All Inputs

- Protective Action Guides (PAGs)
- Relative Biological Effectiveness
- Breathing Rates
- Building Protection Factors
- Exposure to Dose Factors
- ICRP and Lung Clearance
- Instrument Thresholds
- Occupancy Factors**
- Particle Size Distribution

Occupancy Factors

Configure Occupancy Factors for Individual Time Phases

Time Phase	Occupancy
First Year	Inside: 0.0 Outside: 1.00

First Year

Apply to All Time Phases

Occupancy Factors: Enabled

How do you wish to provide Occupancy Factors?

Calculate Occupancy Factors Enter Occupancy Factors Manually

Calculation Inputs

Calculator Tool Coefficients: Default Coefficients

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone	
Days/Week	7	0	[0, 7]
Hours/Day Absent	0.0	0.0	
Hours/Day Sheltered	0.0	0.0	
Hours/Day Unsheltered	24.0	24.0	[0.0, 24.0] [0.0, 24.0]

Occupancy Factors

Inside Occupancy Factor: 0.0 [0.0, 1.00] Fraction

Outside Occupancy Factor: 1.00 [0.0, 1.00] Fraction



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Ensure the Configure Occupancy Factors for Individual Time Phases is checked

If you deleted all the Time Phases EXCEPT First Year, the left side of the panel should show just the First Year

Occupancy Factors Help

Configure Occupancy Factors for Individual Time Phases

Time Phase	Occupancy
First Year	Inside: 0.0 Outside: 1.00

First Year

Apply to All Time Phases

Occupancy Factors: Enabled

How do you wish to provide Occupancy Factors?

Calculate Occupancy Factors Enter Occupancy Factors Manually

Calculation Inputs

Calculator Tool Coefficients: Default Coefficients



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Occupancy Factors should be checked – Enabled

Calculate Occupancy Factors button should be selected

Use the drop-down menu to select User Defined for Calculator Tool Coefficients

Occupancy Factors

Help

Configure Occupancy Factors for Individual Time Phases

Time Phase	Occupancy
First Year	Inside: 0.0 Outside: 1.00

First Year

Apply to All Time Phases

Occupancy Factors: Enabled

How do you wish to provide Occupancy Factors?

Calculate Occupancy Factors Enter Occupancy Factors Manually

Calculation Inputs

Calculator Tool Coefficients: Default Coefficients

- Default Coefficients
- User Defined



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone
Days/Week	2	5
Hours/Day Absent	0	10
Hours/Day Sheltered	12	12

Using the data from the table fill in the appropriate values

Notice that TF calculates the other values and determines the

Calculation Inputs

Calculator Tool Coefficients:

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone	
Days/Week	<input type="text" value="2"/>	<input type="text" value="5"/>	[0, 7]
Hours/Day Absent	<input type="text" value="0.0"/>	<input type="text" value="10.0"/>	
Hours/Day Sheltered	<input type="text" value="12.0"/>	<input type="text" value="12.0"/>	
Hours/Day Unsheltered	<input type="text" value="12.0"/>	<input type="text" value="2.0"/>	
	[0.0, 24.0]	[0.0, 24.0]	

Occupancy Factors

Inside Occupancy Factor:

Outside Occupancy Factor:



RUN CALCULATION

Click the Deposition button

The screenshot shows the software interface for "New Derived Response Levels Calculation - Turbo FRMAC". The top menu bar includes "HOME", "SHARE", "TOOLS", and "HELP". Below the menu bar, there are several toolbars. The "Inputs" toolbar contains "Required", "Other", "Show All", "1992 EPA PAG Manual Emulation Mode" (with an "OFF" toggle), and "Reset Inputs". The "Results" toolbar contains "Dose and Exposure", "Deposition" (highlighted with a yellow arrow), and "Integrated Air". To the right of these are "Dose Parameters" (with a "DP" icon) and "More Mixture Properties". Further right are dropdown menus for "Age Group: Adult" and "Organ: Whole Body". The "Tools" toolbar contains "Dose Rollup Tool". The "View" toolbar contains "Collapse All", "Expand All", "Search", and "Details". The "Window" toolbar contains "Switch Calculations".

The progress dialog box is titled "Progress..." and shows the following progress information:

- Overall:** 94% complete (represented by a blue progress bar).
- Current:**
 - Radionuclide Mixture:** 100% complete (represented by a full blue progress bar).
 - Derived Response Levels:** 100% complete (represented by a full blue progress bar). Sub-task: Calculating Gross Alpha/Beta Derived Response Levels.
 - Decay & Ingrowth Denominator Terms:** 100% complete (represented by a full blue progress bar). Sub-task: Complete.

At the bottom of the dialog, it shows "Elapsed Time:" and a "Cancel" button.



DEPOSITION DRLS - MODIFIED

Final Results displayed

Derived Response Levels | View the calculated results for the Alpha, Beta, and Radionuclide-specific Deposition DRLs.

Deposition Results

- Alpha DRLs
- Beta DRLs
- Radionuclide-Specific DRLs**

Radionuclide-Specific DRLs

Whole Body values are displayed for Adult for a Chronic Commitment Period.

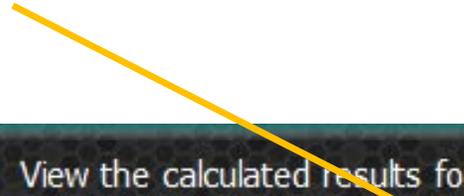
Radionuclide	Form	First Year
⁶⁰ Co	P	15.4
¹⁴⁸ Gd	P	7.73
⁹⁰ Sr	P	23.2
⁹⁰ Y	P	23.2

DRL Units: μCi / m^2



DOSE RATE DRL - MODIFIED

Final Results displayed



Derived Response Levels | View the calculated results for the Dose Rate and Exposure Rate DRLs.

Dose and Exposure Results

- Dose Rate DRLs
- Exposure Rate DRLs

Dose Rate

Whole Body values are displayed for **Adult** for a **Chronic** Commitment Period.

First Year	0.42
------------	------

Dose Rate DRL Units: mrem / hr



INTERPRETING THE RESULTS

Radionuclide	First Year DRL Default Inputs		First Year DRL BPF and OF Applied	
	Deposition DRL $\mu\text{Ci}/\text{m}^2$	Dose Rate DRL mrem/hr	Deposition DRL $\mu\text{Ci}/\text{m}^2$	Dose Rate DRL mrem/hr
^{60}Co	7.34	0.2	15.41	0.42
^{148}Gd	3.68		7.73	
^{90}Sr	11.04		23.17	
$^{90}\gamma$	11.04		23.17	

- By applying protection factors, Deposition and Dose Rate DRLs roughly double
- This implies it will take approximately twice as much radioactive material deposited on the ground before the PAG may be exceeded
- The decision makers may be able to **greatly reduce or even avoid a Relocation Protective Action Recommendation** depending on field measurements



ADVANCED INGESTION INPUTS AND CALCULATIONS



OTHER INGESTION INPUTS – CROP DRLS

Populated with default values, and do not **need** to be altered to run a calculation

A thorough understanding of the inputs and scenario in question is recommended before the user changes values from the defaults

Required Other Show All Reset Inputs Crop DRL

Inputs

2 Crop Pathway Settings: Enter a value for Time t

Radionuclide Mixture: The Mixture must contain Import a Mixture.

Crop Derived Response Levels

Other Inputs

- Advanced Mixture Properties
- Crop Weathering
- Weathering Correction



OTHER INGESTION INPUTS – CROP DRLS

Advanced Mixture Properties

- Allows for the user to change the fraction of the diet contaminated, crop retention factor, and crop transfer factors for the selected radionuclides

Advanced Mixture Properties

Data may not be displayed for certain results. Select other results to see different properties.

Mixture **Radionuclides**

Editing the Advanced Mixture Inputs will affect your Results.

Select a Radionuclide from the Mixture to view additional properties below.

Form	Radionuclide	Half-Life	Decay Constant	Days of Intake
	¹³⁷ Cs	9.52E8	7.28E-10	3.65E2
	¹³⁴ Cs, ¹³⁷ Cs Group	9.52E8	7.28E-10	3.65E2
	¹⁴⁷ Gd	1.37E5	5.05E-6	10.55
	⁹⁰ Sr	9.09E8	7.63E-10	3.65E2

s s⁻¹ d

Cs-137

- Fraction of Diet Contaminated**
- RBE Values
- Crop Retention Factor
- Crop Transfer Factor

Age Group	Contamination
Adult	0.3
Fifteen Year Old	0.3
Ten Year Old	0.3
Five Year Old	0.3
One Year Old	0.3
Three Month Old	0.3

Fraction [1.00E-100, 1.0]

⚠ FDA Radionuclides are present in this mixture. Many values of an FDA Radionuclide are N/A.



OTHER INGESTION INPUTS – CROP DRLS

Crop Weathering

- Allows the user to adjust the rate at which the mixture is weathered from the surface of the crops **or** the removal half-life of the mixture from the crop surface

Crop Weathering

Crop Weathering Removal Constant:
[1.90E-3, 5.99E4]

Crop Weathering Removal Half Life:
[1.16E-5, 3.65E2]

Formula
Crop Weathering Removal Constant = $\ln(2) / \text{Crop Weathering Removal Half Life}$

Weathering Correction

- Allows the user to change the coefficients of the weathering equation.
- This represents the movement of the radioactive material away from the area of concern either via migration into the soil column or through runoff.

Weathering Correction Help

Weathering Correction: Enabled

Weathering Coefficients:

Coefficient #1:
[0.0, 1.0]

Coefficient #2:
[0.0, 1.0]

Exponent Coefficient #1:
[1.00E-20, 1.0]

Exponent Coefficient #2:
[1.00E-20, 1.0]



EFFECTS OF CROP WEATHERING ON MILK AND MEAT DRLS

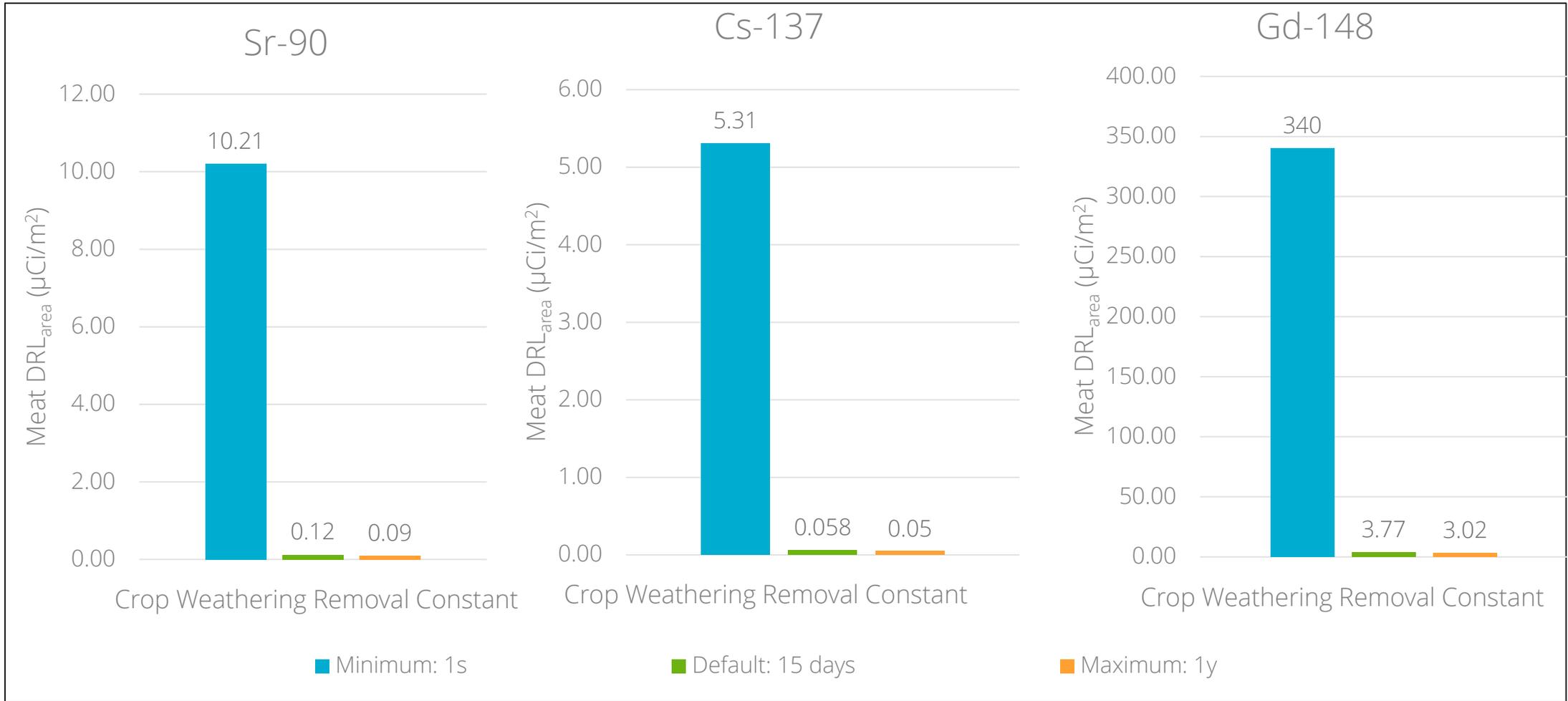
Assumptions

- Mixture: ^{90}Sr , ^{137}Cs , ^{148}Gd
- $t_n = 0.5$ d
- $t_g = 5$ d
- $t_{h,\text{meat}} = 15$ d
- $t_m = 20$ d
- All other inputs set to the defaults

Crop Weathering Removal Half-Lives

- Default: 15 d
- Min: 1 sec
- Max: 1 yr

RESULTS



Weathering off the crop can have a substantial effect on the meat DRL value



ADVANCED REQUIRED INPUTS – CROP DRLS

Crop Pathway Settings Help

Enter the time settings for this Calculation.

Evaluation Time: d ▼
[0.0, 1.83E4]

Time to Harvest: d ▼
[0.0, 1.83E4]

Time to Market (after Harvest): d ▼
[0.0, 1.83E4]

Yes Was crop growing above the surface at the time of deposition?
 No Selecting 'No', will set the 'Crop Retention Factor' to 0.0

Verify the default values are appropriate for this Calculation.

Crop Yield: Produce ▼ kg ▼ / m² ▼
(0.0, 1.00E4]

Crop Type: Leafy Vegetables ▼

Mass Conversion Factor: Sync with Crop Type ▼ kg_{dry} ▼ / kg_{wet} ▼
[0.0, 1.0]

Mature Root Depth: Sync with Crop Type ▼ m ▼
[1.00E-3, 10.0]

Mixing Depth: m ▼
(0.0, 10.0]

Soil Density: kg ▼ / m³ ▼
(0.0, 1.00E4]

⊗ Enter a value for Time to Harvest and press Enter.

Values are set to the defaults

ADVANCED REQUIRED INPUTS – MILK AND MEAT DRLS



Verify the default values are appropriate for this Calculation.

L Livestock:	Beef Cow	▼			
M Fodder Intake Rate:	50.0	kg / d	▼		
(0.0, 1.00E3]					
A Forage Intake Rate:	50.0	kg / d	▼		
(0.0, 1.00E3]					
A Soil Intake Rate:	0.5	kg / d	▼		
(0.0, 1.00E3]					
W Water Intake Rate:	49.99	L / d	▼		
(0.0, 1.00E3]					
M Fodder Contaminated:	1.0	Fraction	▼		
[0.0, 1.0]					
A Forage Contaminated:	1.0	Fraction	▼		
[0.0, 1.0]					
W Water Contaminated:	1.0	Fraction	▼		
[0.0, 1.0]					
A Crop Yield:	Forage	▼	0.7	kg / m ²	▼
(0.0, 1.00E4]					
A Crop Type:	Forage				
A Mass Conversion Factor:	Sync with Crop Type	▼	0.22	kg _{dry} / kg _{wet}	▼
[0.0, 1.0]					
A Mature Root Depth:	Sync with Crop Type	▼	0.6	m	▼
[1.00E-3, 10.0]					
A Mixing Depth:	1.00E-3	m	▼		
(0.0, 10.0]					
A Soil Density:	1.60E3	kg / m ³	▼		
(0.0, 1.00E4]					

All values, including livestock type, are set to the defaults



ADVANCED REQUIRED INPUTS – MILK AND MEAT DRLS

Verify the default values are appropriate for this Calculation.

L Livestock:	Goat		
M Fodder Intake Rate:	6.0	kg / d	
	(0.0, 1.00E3]		
A Forage Intake Rate:	6.0	kg / d	
	(0.0, 1.00E3]		
A Soil Intake Rate:	6.00E-2	kg / d	
	(0.0, 1.00E3]		
W Water Intake Rate:	8.0	L / d	
	(0.0, 1.00E3]		
M Fodder Contaminated:	0.5	Fraction	
	[0.0, 1.0]		
A Forage Contaminated:	0.5	Fraction	
	[0.0, 1.0]		
W Water Contaminated:	0.5	Fraction	
	[0.0, 1.0]		
A Crop Yield:	Forage	0.7	kg / m ²
		(0.0, 1.00E4]	
A Crop Type:	Forage		
A Mass Conversion Factor:	Sync with Crop Type	0.22	kg _{dry} / kg _{wet}
		[0.0, 1.0]	
A Mature Root Depth:	Sync with Crop Type	0.6	m
		[1.00E-3, 10.0]	
A Mixing Depth:	1.00E-3	m	
	(0.0, 10.0]		
A Soil Density:	1.60E3	kg / m ³	
	(0.0, 1.00E4]		

Changing livestock type changes intake rates to match. User can also determine how much of the intake pathway is contaminated by changing the fractions below the intake rates

Adjusting for livestock type and fraction of diet contaminated allows for answering farm specific questions, including application of protective actions such as incorporation of uncontaminated feed, forage, and/or water

ADVANCE REQUIRED INPUTS – MILK AND MEAT DRLS



Milk and Meat pathways for cows assume that only one pathway is contaminated at any given time. This could be unrealistic.

In actuality, the "one contaminated pathway" assumption means that only one pathway's contamination is variable in the calculation.

It is possible to consider the contamination of multiple pathways simultaneously, but this requires additional computation outside of the Turbo FRMAC software.

ADVANCED ADDITIONAL INPUTS – MILK AND MEAT DRLS



Weathering

- Weathering when applied to Milk and Meat ingestion calculations does not just affect how much material is removed from the crop by processes such as wind.
- The weathering factor for Milk and Meat is a modifier in the ingested soil, so rate of weathering from the soil will also contribute to the amount of contamination in the cow over and above what was in or on the crop itself

EXAMPLE – BUT WHAT ABOUT THE REINDEER?



The March 2011 Fukushima Daiichi nuclear incident had agricultural impact that reached Alaska. Initial concern was any dairy and/or beef cows in the affected area. Assessment Scientists were informed that cows were kept sheltered during the winter months.

The follow-up question from local farmers: "But what about the Reindeer?"

Reindeer comprise a substantial portion of dairy and meat agriculture for Alaska, US.

Assessment Scientists had to account for this in their assessments.

What are some of the ways that you could account for animal products, like reindeer, not included in Turbo FRMAC?



THINGS TO CONSIDER IN NON-STANDARD ANIMAL PRODUCT CALCULATIONS

What do reindeer eat? How much?

Answer: 5 kg/d of Lichen

Is the transfer factor into reindeer milk or meat different than cows?

Answer: Yes. Transfer factors into reindeer milk is $1.9E-01$ uCi/l per uCi/d

Is the crop yield of lichen different than other forage types?

Answer: Yes. $Y=0.75$ kg_{wet}/m²

Is the soil intake off of lichen different?

Answer: Yes. $ASDIR_{soil} = 0.3$ kg_{wet}/d



THINGS TO CONSIDER IN NON-STANDARD ANIMAL PRODUCT CALCULATIONS

Does reindeer milk have a different density?

Answer: Not really. Density of reindeer milk is typically 1 kg/L

Is the soil intake off of lichen different?

Answer: Yes. $ASDIR_{soil} = 0.3 \text{ kg}_{wet}/d$

References:

- Radiocesium Uptake in Reindeer on Natural Pasture, B.E.V. Jones, D. Eriksson, M. Nordkvist, *The Science of the Total Environment*, *5 (1989), 207 - 212.
- *Reindeer Health Aid Manual*, Dieterich, RA, Morton, JL et al., AFES Misc. Pub 90-4, CES 100H-00046, Univ. of Alaska and U.S. Department of Agriculture, 1990
- Average, "Part II: An inventory of lichen species that are used by people," <http://web.uvic.ca/~stucraw/part2AM.html>
- *Transfer of 85Sr and 134Cs from the diet of reindeer foetuses and milk*, I. Skuterud, H. Gjostein et al, *Radiation Environ Biophysics* (2005) 44:107-117.



WORK THE PROBLEM

Assume the forage is contaminated with ^{137}Cs . Determine the $\text{Milk_DRL}_{\text{area}}$ for the reindeer for ^{137}Cs .

Use the following assumptions in your calculation

Transfer Factor	1.9E-01 ($\mu\text{Ci/l}$ per $\mu\text{Ci/d}$)
Crop Retention Factor	0.5
Animal Forage Daily Intake Rate	5 ($\text{kg}_{\text{wet}}/\text{d}$)
Crop Yield	0.75 ($\text{kg}_{\text{wet}}/\text{m}^2$)
Animal Soil Daily Intake Rate	0.3 ($\text{kg}_{\text{soil}}/\text{d}$)
Fraction of Diet Contaminated	1
Time to Market	2 days
Time to Grazing	1 day
Time to Harvest	2 days
Milk Density	1 kg/L



START A NEW CALCULATION

Start Your Calculation | Choose the type of Calculation you wish to perform.

- 1 Browse Categories**
 - Public Protection**
Evaluate the potential impacts to members of the public from exposure to radiological materials in the air and/or deposited on the ground.
 - Worker Protection**
Establish worker protection guidelines (e.g., turn-back limits and derived response levels).
 - Ingestion**
Evaluate the potential impacts from radiologically contaminated food.
 - Supplemental**
Perform additional calculations to support radiological assessments.
- 2 Select Calculation**
 - Intervention Levels**
Calculate the concentration of a radionuclide in food that is likely to cause an Ingestion Dose equal to the ingestion PAG.
 - DRLs**
 - Crop DRLs**
Calculate the areal activity of a radionuclide on the ground that may cause a crop growing in the area to be contaminated at the Intervention Level.
 - Meat DRLs**
Calculate the activity of a radionuclide in an animal's diet that may cause the animal's meat to be contaminated at the IL.
 - Milk DRLs**
Calculate the activity of a radionuclide in an animal's diet that may cause the animal's milk to be contaminated at the IL.
 - EPA Water DRLs**
Calculate radionuclide concentration(s) in water that is likely to cause an Ingestion Dose equal to the drinking water PAG.
- 3 Choose Template**
 - Blank**
Create a Calculation using all default inputs.
 - Copy from Existing**
Make a copy of a saved Calculation to get started.



NAME AND DESCRIBE YOUR CALCULATION

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture ✖

Name and Description

Help

Name: ✖
26 characters entered

Description: ✖
140 characters entered



CONFIRM HUMAN INTAKE RATES

For this calculation, we will be using the default Human Intake Rates.

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture ✘
- Milk Pathway Settings ✘
- ICRP & FDA Settings

Human Intake Rates

Human Intake Type: Milk

Milk Category: Total Daily Intake Reset...

All rates are editable for every category.

Age Group	Human Intake Rate
Adult	2.59
Fifteen Year Old	2.38
Ten Year Old	2.14
Five Year Old	1.81
One Year Old	1.38
Three Month Old	1.14

kg / d
[1.00E-10, 10.0]



BUILD YOUR MIXTURE

Select ^{137}Cs from your drop down

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture ✖
- Milk Pathway Settings ✖
- ICRP & FDA Settings
- Protective Action Guides (PAGs)

Radionuclide Mixture

Name:

Description:

Add Radionuclide:

✖ +

Searching All Radionuclides

Rad Cs-137

Import Export & Email Manage Daughters Age Scale View

2015 ICRP 60

0 parents, 0 daughters, 0 total radionuclides, 0 total forms Truncation: ON Equilibrium: ON

i Activity values for the Radionuclides are not needed for this Mixture.

✖ The Mixture must contain 1 or more Radionuclides. Add Radionuclides or Import a Mixture.



BUILD YOUR MIXTURE

Since ^{137}Cs is an FDA radionuclide, the mixture panel populates the cesium group

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings ✖
- ICRP & FDA Settings
- Protective Action Guides (PAGs)

Radionuclide Mixture

Name:

Description:

Add Radionuclide: +

✖ + ↓ ↑ ↕ Age 2015 ICRP 60 Scale View

Radionuclide
<input type="checkbox"/> ✖ FDA ^{137}Cs
<input type="checkbox"/> $^{137\text{m}}\text{Ba}$
<input type="checkbox"/> FDA ^{134}Cs , ^{137}Cs Group

2 parents, 1 daughter, 3 total radionuclides, 3 total forms Truncation: ON Equilibrium: ON

+ Activity values for the Radionuclides are not needed for this Mixture.



MILK PATHWAY TIME SETTINGS

Set your time settings

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings

Milk Pathway Settings

Enter the time settings for this Calculation.

 Evaluation Time:	<input type="text" value="0.5"/>	d	▼
	[0.0, 1.83E4]		
 Time to Grazing:	<input type="text" value="1.0"/>	d	▼
	[0.0, 3.66E2]		
 Time to Harvest:	<input type="text" value="2.0"/>	d	▼
	[0.0, 1.83E4]		
 Time to Market (after Harvest):	<input type="text" value="2.0"/>	d	▼
	[0.0, 1.83E4]		



MILK PATHWAY SETTINGS

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings
- ICRP & FDA Settings
- Protective Action Guides (PAGs)

Verify the default values are appropriate for this Calculation.

Livestock: /

Fodder Intake Rate: /

Forage Intake Rate: /

Soil Intake Rate: /

Water Intake Rate: /

Fodder Contaminated:

Forage Contaminated:

Water Contaminated:

Crop Yield: /

Crop Type:

Mass Conversion Factor: /

Mature Root Depth:

Mixing Depth:

Soil Density: /

Select Livestock type as User Defined from the dropdown. This will unlock the Intake Rate boxes.



MILK PATHWAY SETTINGS

Milk DRLs | Review and edit the most commonly used inputs for the calculations.

Verify the default values are appropriate for this Calculation.

Required Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings
- ICRP & FDA Settings
- Protective Action Guides (PAGs)

☐ Livestock: User Defined

☐ Fodder Intake Rate: 50.0 kg / d
(0.0, 1.00E3]

☐ Forage Intake Rate: 5.0 kg / d
(0.0, 1.00E3]

☐ Soil Intake Rate: 0.3 kg / d
(0.0, 1.00E3]

☐ Water Intake Rate: 59.99 L / d
(0.0, 1.00E3]

☐ Fodder Contaminated: 1.0 Fraction
[0.0, 1.0]

☐ Forage Contaminated: 1.0 Fraction
[0.0, 1.0]

☐ Water Contaminated: 1.0 Fraction
[0.0, 1.0]

☐ Crop Yield: User Defined 0.75 kg / m²
(0.0, 1.00E4]

☐ Crop Type: Forage

☐ Mass Conversion Factor: Sync with Crop Type 0.22 kg_{dry} / kg_{wet}
[0.0, 1.0]

☐ Mature Root Depth: Sync with Crop Type 0.6 m
[1.00E-3, 10.0]

☐ Mixing Depth: 1.00E-3 m
(0.0, 10.0]

☐ Soil Density: 1.60E3 kg / m³
(0.0, 1.00E4]

Populate necessary inputs with given information



CHANGING THE CROP RETENTION AND TRANSFER FACTOR

Crop retention factors and transfer factors are found in the Other Inputs and can be changed for each radionuclide individually

Milk DRLs | Show all inputs (both Required and Other) that can impact the calculations.

Show All Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings
- ICRP & FDA Settings
- Protective Action Guides (PAGs)
- Advanced Mixture Properties** ⚠
- Liquid Densities
- Crop Weathering
- Weathering Correction

Advanced Mixture Properties

Data may not be displayed for certain results. Select other results to see different properties.

Mixture: **Radionuclides**

Editing the Advanced Mixture Inputs will affect your Results.

Select a Radionuclide from the Mixture to view additional properties below.

Form	Radionuclide	Half-Life	Decay Constant	Days of Intake
	¹³⁷ Cs	9.52E8	7.28E-10	3.65E2
	¹³⁴ Cs, ¹³⁷ Cs Group	9.52E8	7.28E-10	3.65E2

s s⁻¹ d

Cs-137

- Fraction of Diet Contaminated
- RBE Values
- Crop Retention Factor**
- Milk Transfer Factor
- Forage Transfer Factor

Crop Retention Factor

Crop Retention Factor:
[0.0, 1.0]

⚠ FDA Radionuclides are present in this mixture. Many values of an FDA Radionuclide are N/A.



CHANGING THE TRANSFER FACTOR

Select Milk Transfer Factor and input the given value

Milk DRLs | Show all inputs (both Required and Other) that can impact the calculations.

Show All Inputs

- Name and Description
- Human Intake Rates
- Radionuclide Mixture
- Milk Pathway Settings
- ICRP & FDA Settings
- Protective Action Guides (PAGs)
- Advanced Mixture Properties
- Liquid Densities
- Crop Weathering
- Weathering Correction

Advanced Mixture Properties

Data may not be displayed for certain results. Select other results to see different properties.

Mixture **Radionuclides**

Editing the Advanced Mixture Inputs will affect your Results.

Select a Radionuclide from the Mixture to view additional properties below.

Form	Radionuclide	Half-Life	Decay Constant	Days of Intake
	¹³⁷ Cs	9.52E8	7.28E-10	3.65E2
	¹³⁴ Cs, ¹³⁷ Cs Group	9.52E8	7.28E-10	3.65E2

s s⁻¹ d

Cs-137

- Fraction of Diet Contaminated
- RBE Values
- Crop Retention Factor
- Milk Transfer Factor**
- Forage Transfer Factor

Milk Transfer Factor

Reset to Defaults

Milk Transfer Factor:

[0.0, 2.31E6]

FDA Radionuclides are present in this mixture. Many values of an FDA Radionuclide are N/A.



LIQUID DENSITIES

Milk density is specific to the animal. To change this, click on the Liquid Densities button. Change the Milk Density to 1 kg/L

Advanced Mixture Properties 

Liquid Densities 

Crop Weathering

 FDA Radionuclides are present in this mixture. Many values of an FDA Radionuclide are N/A.

 Liquid Densities

Milk Density: kg  / L 
[1.00E-2, 100.0]

Water Density: kg  / L 
[1.00E-2, 100.0]



RUN CALCULATION

Required Other Show All Reset Inputs **Milk DRL for Area** Milk DRL for Mass Milk DRL for Water Intervention Levels

Age Group: Most Conservative (excludes Three Month Old)

Organ: Most Conservative

Inputs Results

RESULTS DISPLAYED



Milk DRLs | View the calculated results for Milk Derived Response Levels for Area.

Milk DRL for Area Results

Ingestion Derived Response Levels

Ingestion Derived Response Levels

Most Conservative Organ values are displayed for **Most Conservative** Age Group (excludes Three Month Old for non-FDA radionuclides) for a **Chronic** Commitment Period.

Radionuclide	Age Group	Organ	DRL Value
 ¹³⁷ Cs	Adult	Whole Body	5.74E-2
 ¹³⁴ Cs, ¹³⁷ Cs Group	Adult	Whole Body	2.09

μCi / m²



FINAL EXERCISE

Questions



INSTRUCTIONS

With the remaining time, we will be completing a Do It Yourself exercise that will touch on the concepts learned through the two completed training sessions. If everyone has completed the exercise before the end of the session, we will go over the answers together.

If we run out of time, please email your answers to Autumn at aekalin@sandia.gov we will review your answers and return the solutions to you!

Have fun, and good luck!



PART 1 – GENERAL TRIVIA

1. What is a PAG?
2. What is a DRL?
3. How many Dose Pathways are considered by FRMAC Public Protection Methods?
4. The point in time, relative to the start of the event for which the calculation is being performed is called what?
5. What is the default consumption period for determining an Ingestion Intervention Level?
6. True or False: it is not possible to adjust Crop/Milk/Meat DRL calculation inputs to customize the calculation to crops and livestock not included in the Turbo FRMAC software.



PART 2 – TURBO FRMAC EXERCISE

Scenario:

The Springfield Nuclear Power Plant (PWR) declared a General Emergency due to a main steam line rupture. The rupture resulted in an uncontrolled, short-term release to the environment.

Use the following source inventory (mixture) for all the Turbo FRMAC calculations. Include all daughters:

Radionuclide	Activity per Area ($\mu\text{Ci}/\text{m}^2$)
Ba-140	6500
Ce-144	200
Cs-134	1600
Cs-137	1000
I-131	18100
Sb-127	600
Sr-90	200



PART 2 – TURBO FRMAC EXERCISE

1. What is the Early Phase Deposition DRL for Sr-90 in $\mu\text{Ci}/\text{m}^2$?
2. Which Age Group does the DRL calculated in #22 apply to?
3. What is the 2nd year Dose Rate DRL for the mixture in Rem/s?
4. Which FIL in $\mu\text{Ci}/\text{kg}$ would you recommend for Sb-127?
5. Which age group has the most restrictive IL for Cs-137?
6. What is the 1 Year Old Thyroid IL for I-131 in $\mu\text{Ci}/\text{kg}$?
7. What is the Milk_DRL_{area} for Ba-140 in pCi/cm^2 (Assume an Evaluation Time of 5 days, a Time to Grazing of 14 days and a Time to Harvest of 16 days)?
8. What is the Crop DRL for I-131? (Assume a wheat (Grain) crop, an Evaluation Time of 30 days and a Time to Harvest of 50 days) ?



PART 1 - ANSWERS

1. Protective Action Guide
2. Derived Response Level
3. 1-4 pathways
4. Evaluation time
5. 1 year
6. False. Ingestion calculations can be customized based on data the user has to fit non-included crops and animals



PART 2 - ANSWERS

1. 7.88 $\mu\text{Ci}/\text{m}^2$
2. Adult
3. 2.66E-07 Rem/s
4. 4.54 $\mu\text{Ci}/\text{kg}$
5. Adult
6. 4.59E-03 $\mu\text{Ci}/\text{kg}$
7. 1250 pCi/cm^2
8. 2.23 $\mu\text{Ci}/\text{m}^2$



Thank you!

Questions?



REVISING THE SOURCE TERM



SOURCE TERM ESTIMATES

Early in a response, it may be necessary to provide our best guess for the release source term

Nuclear Power Plant or Facility Accidents

- Nuclear Regulatory Commission (NRC)
 - Facility/Reactor Inventory
 - RASCAL models of potential accident scenarios
- Subject Matter Experts
 - For "what if" scenarios at nuclear facilities



SOURCE TERM - RASCAL MODELS

Primary uses for Assessment

- Model release scenario to estimate source term and release fractions
- Examine dose & consequence projections from local licensee and regulator
 - Examine what other information has be generated locally
 - Compare facility generated projections to RASCAL projections, if applicable



INCORPORATING ATMOSPHERIC MODELING

Establish communication with NARAC analyst or response coordinator

- Identify any models that have been created already
- Review source term and release scenario information in model(s)

Provide source term to NARAC for modeling

- Communicate key assumptions for calculations with NARAC
 - Observation time, shelter assumptions, source term used, etc.
 - Typically, providing the RASCAL file for the event is a good starting point



FRMAC DATA REVIEW PROCESS

As an event progresses and data is collected, this data must be reviewed and integrated into the existing Common Operating Picture (COP) to update the source term.

Data Quality (DQ) Review: Was the data collected properly?

- Correct metadata: date/time, location, equipment used
- Find entry errors: correct unit/prefix, units match radiation type, etc.
- Performed by Monitoring Division with assistance from Assessment as needed

Data Integration (DI) Review: Does the data make sense?

- Compare data against the COP
- Compare data from all sources for consistency
- Performed by Assessment Division



DATA INTEGRATION REVIEW

Data Integration Review and the COP

- The data integration review compares collected data against the models and previous data incorporated into the COP
- Comparison with COP serves 2 purposes:
 - Evaluation of data against all models and data collected to identify outliers or potential issues with measurements (bad detectors, etc.)
 - Evaluation of the models in the COP to ensure they are correlated with real-world measurements and samples

Potential Outcomes of Data Integration Review

- New data consistent with existing data and COP: **Approved**
- New data inconsistent with existing data and COP
 - Collect additional data to investigate: **Under Review**
 - If sufficient data present to confirm new measurement is an outlier: **Reject**
- New data inconsistent with COP
 - Collect additional data to investigate: **Under Review**
 - Data sufficient to confirm COP needs to be revised: Revise COP and repeat review

DATA INTEGRATION (DI) REVIEW – SOURCE TERM



Evaluate data against the source term model (mixture)

- Are Isotopic Ratios Consistent?
- Are Alpha/Beta, Alpha/Gamma, Beta/Gamma Ratios Consistent?
- Compare Isotopic Activity Concentration vs. Dose Rate or Contamination Values

Importance to evaluating data

- Determine if the modeled source term is complete
 - Are there any missing isotopes?
 - Is there fractionation of released inventory during transport or deposition?

DI REVIEW – SOURCE TERM, LABORATORY RESULTS



Laboratory Analysis is essential to confirm isotopic ratios in the soil and air

- Deposition and in-situ sample analysis
 - Most common samples for evaluating deposition & source term
 - If available, air samples collected during plume passage can also be used to evaluate the released inventory and predict deposition
- Identify Marker Isotope for evaluation
 - Marker radionuclide is one that is easy to measure and identify (e.g. Cs-137)
- Calculate ratio of each isotope result per sample to marker isotope result and compare to expected isotope ratios from source term

DI REVIEW – SOURCE TERM, SURVEY RESULT MIXTURE RATIOS



Calculate alpha/beta, beta/gamma, and alpha/gamma ratios

- Calculate net values for all survey measurements
- Calculate ratios for each survey location using the net measurements

Note: Do not calculate ratios for radiation types not emitted by source mixture (e.g., no alpha/beta ratio for a Cs-137 release)

Calculate expected ratios for source mixture

- Using Turbo FRMAC, calculate DRLs using an evaluation time corresponding to the data being reviewed
- The expected ratio for the source term at the observation time used is the ratio of the DRLs
 - Alpha/Beta ratio should be the Alpha DRL/Beta DRL

DI REVIEW – SOURCE TERM, EVALUATING RATIO RESULTS



Compare ratios for samples or surveys to expected ratio

- Look for trends
 - e.g., Alpha/Gamma ratio is consistently higher than expected
 - Consistent trends are an indication to consider revising COP source term
- Identify potential outliers
 - Ratios are very sensitive to measurement uncertainty and variance
 - There should be a random distribution of ratios around the expected value
 - Choose trigger levels to investigate ratios
 - For example, in the recovery phase a variance greater than 30% from expected values might be flagged

α/β

DI Review for source term

- Ratios in agreement with expected values from COP: No action.
- Ratios do not agree with expected values based on COP
 - Data is sufficient to suggest revision of COP: Recommend revision of COP
 - Data not sufficient: Flag as under review and request additional sampling/measurements
- For apparent outliers
 - Flag as under review and determine if discrepancies can be explained or if more data is needed



TYPES OF DATA THAT INFORM THE SOURCE TERM

- Particle size distribution
- Weather/weather changes
- Ground deposition measurements
- Changes to the release
 - Short term versus long term
 - Content of release
 - Energy of the release
 - E.g. fire is put out **OR** fire turns to an explosion
- Air sampler measurements