

Introduction to FRMAC Dose Assessment Methodology and Turbo FRMAC Software



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EPA Protective Action Guide (PAG) Manual

Final Approval, January 2017



EPA-400/R-17/001 | January 2017
www.epa.gov/radiation/protective-action-guides-pags

On January 11, 2017, EPA Deputy Assistant Administrator for the Office of Water, Joel Beauvais, signed a Federal Register notice announcing the finalization and addition of drinking water guidance to the PAG Manual. This copy is being provided to inform the public about EPA's intentions, and will be replaced with the official document upon publication of the Federal Register notice. This document is a prepublication version. We have taken steps to ensure the accuracy of this version, but it is not the official version.

PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents



<https://www.epa.gov/radiation/protective-action-guides-pags>



EPA PAG Manual Revision Key Changes

- Incorporates FDA's recommended PAG of **5 rem projected Child Thyroid Dose** for administration of stable iodine (KI)
- Removes the **25 rem Adult Thyroid Dose** and the **50 rem Skin Dose** Evacuation PAGs
- Removes the **50-year, 5 rem Relocation PAG**
- Provides guidance for reentry, late phase cleanup and waste disposal
- Adopts the **FDA's 1998 Food PAGs**



PAG Manual Guidance – Time Phases

Time Phase	Start	Duration	Protective Actions
Early	Begins with the radiological release	May last hours to days; Generally considered to last 4 days (~96 hours)	Evacuation and/or Shelter in Place
Intermediate	Release under control or terminated	1 st Year 2 nd & Subsequent Years	Relocation
Late	Transition from strategies driven by urgency, to strategies aimed at reducing longer-term exposures	Not Defined	Relocation

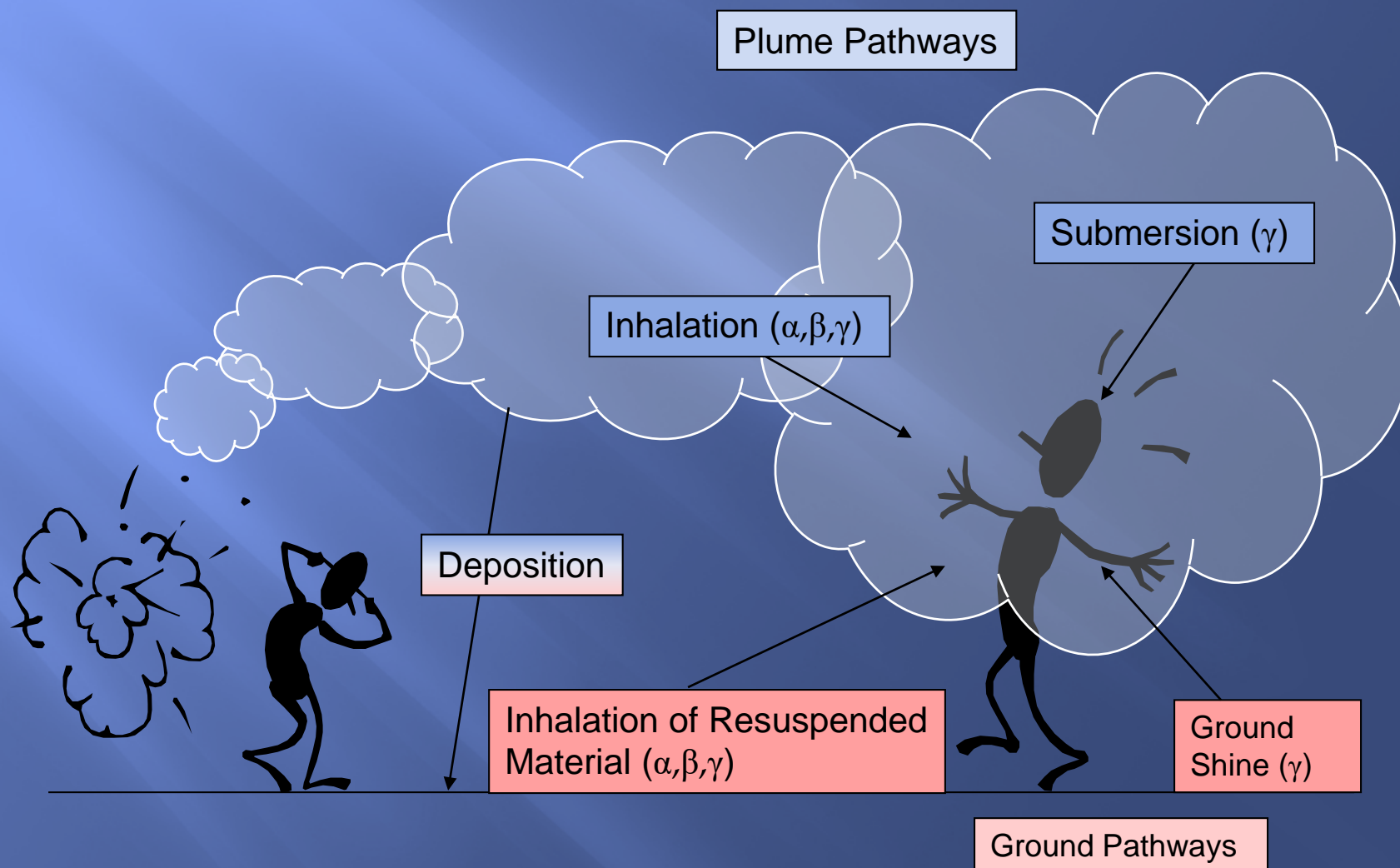


PAGs

Early Phase		
Protective Action Recommendation	PAG (Projected Dose)	Comments
Sheltering-in-Place or Evacuation	1-5 rem	Evacuation (or, for some situations, sheltering-in-place) should be initiated when projected dose is 1 rem
Administration of prophylactic drugs – KI	5 rem to child thyroid from iodine exposure	May require approval of state medical officials (or in accordance with established emergency plans)
Intermediate Phase		
Relocate the general population	2 rem	1 st year following the event
Relocate the general population	0.5 rem	In the 2 nd and subsequent years
Late Phase		
Relocate the general population	NA	PAGs will not be used to guide restoration and recovery



Release Exposure Pathways





Public Protection Exposure Pathways

Early Phase

1. **Inhalation** of radioactive materials in the plume
2. **Direct exposure** from radioactive materials in the plume
3. **Inhalation** of ground-deposited radionuclides resuspended into the breathing zone
4. **Direct exposure** from “groundshine” from deposited radioiodines and particulates

Intermediate & Late Phases

1. **Inhalation** of ground-deposited radionuclides resuspended into the breathing zone
2. **Direct exposure** from “groundshine” from deposited radioiodines and particulates



FDA Ingestion PAG Manual

ACCIDENTAL RADIOACTIVE CONTAMINATION OF HUMAN FOOD AND ANIMAL FEEDS: RECOMMENDATIONS FOR STATE AND LOCAL AGENCIES





FDA Ingestion PAGs

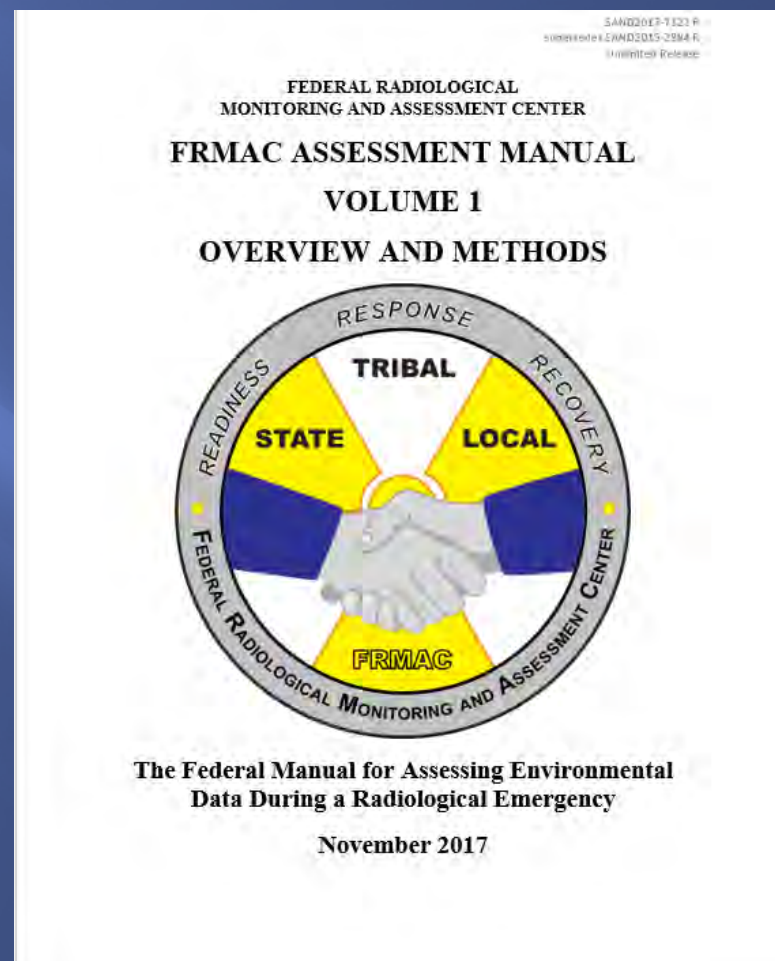
Protective Action Recommendation	PAG (Projected Dose)	Comments
See Below	0.5 rem (E_{50}) 5 rem (H_T)	Whichever is more limiting (Whole Body or Organ) from ingestion of contaminated food in 1 st year

Ingestion Protective Action Recommendations	
All foods	Isolate by temporary embargo until survey and initial sampling is completed Determine whether condemnation or other disposition is appropriate
Milk	Hold for decay or divert to other products involving adequate decay during processing (e.g., cheese, butter, dry milk solids, or evaporated milk)
Fruits and Vegetables	Wash, brush, scrub or peel to remove surface contamination Preserve by canning, freezing, dehydration, or storage to permit decay
Grains	Process by milling and polishing to remove surface contamination
Animals	Move to shelter and/or corral; provide protected feed and water



FRMAC Assessment Manual

- Latest Revision
November 2017
- Available on
Nevada National Security Site



http://www.nnss.gov/pages/programs/frmac/frmac_documentsmanuals.html



FRMAC Assessment Manual

- Provides the technical basis for FRMAC Dose Assessments
- Provides the technical basis for the Turbo FRMAC[®] Software Package
- Provides updated tabulated reference data for default assessment conditions (e.g., Time Phases, PAGs, likely nuclides of concern)

NOTE: The FRMAC Assessment Division strives to implement the best technical health physics, however these may differ from other agencies due to a difference in alternate assumptions



FRMAC Assessment Methods

FRMAC Assessment Working Group (AWG) develops and implements consistent, defensible and state-of-the-art radiological assessment methods across all the represented agencies/organizations

$$CED = DFIR_{age,f} * \sum_i^n \left(FFC_i * FC_i * IngDC_{organ,i,age} * \left(\frac{1 - e^{-(\lambda_i * t)}}{\lambda_i} \right) \right)$$



What is Turbo FRMAC?

- Turbo FRMAC automates FRMAC Assessment Manual methods
- Turbo FRMAC eliminates most human errors
- Turbo FRMAC is a deployable software application
- Turbo FRMAC is not a replacement for Health Physics knowledge and experience





Accessing Turbo FRMAC

- Software may only be issued to Federal, State, Tribal, Local responders with Justification
- Registration required via the following site:

<https://nirp.sandia.gov/>

NUCLEAR INCIDENT RESPONSE PROGRAM

NIRP

Home

Software

Welcome

Login Register

Our Mission

The NIRP program provides research and technical solutions, expert analysis, and highly trained emergency...

News and Updates

Latest Software Releases

Turbo FRMAC 2015



Turbo FRMAC 2018



New
Calculation



Open
Calculation



Watch Help
Videos



FEMA



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PUBLICLY AVAILABLE



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., stay-times, turn-back limits).

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.

Projected Public Dose
Calculate the dose from exposure to a release of radioactive material.

Dose Parameters
Calculate the External, Inhalation, and Total Dose Parameters.

Nuclear Fallout Calculations

Nuclear Fallout Doses
Calculate the Doses for a deposition of radioactive fallout after a nuclear detonation.

Nuclear Fallout Stay Time
Calculate the Stay Time for a deposition of radioactive fallout after a nuclear detonation.

Nuclear Fallout DRLs
Calculate the Nuclear Fallout DRLs for a deposition of radioactive fallout after a nuclear detonation.

Time Varying Calculations

Varying Evaluation Time
Calculate a curve of the DRL for a fixed time phase at different evaluation times.

Projected Return Time
Calculate a curve of the DRL at the fixed evaluation time for shifting time phases. Answers questions like: 'When can I go home?' or 'When will the limit not be exceeded?'

Return Thresholds
Calculate the DRL for the beginning of the time phase for a shifting time phase. Answers questions like: 'Can they go home today?' or 'Will the limit be exceeded now?'



3 Choose Template

Blank
Create a Calculation using all default inputs.

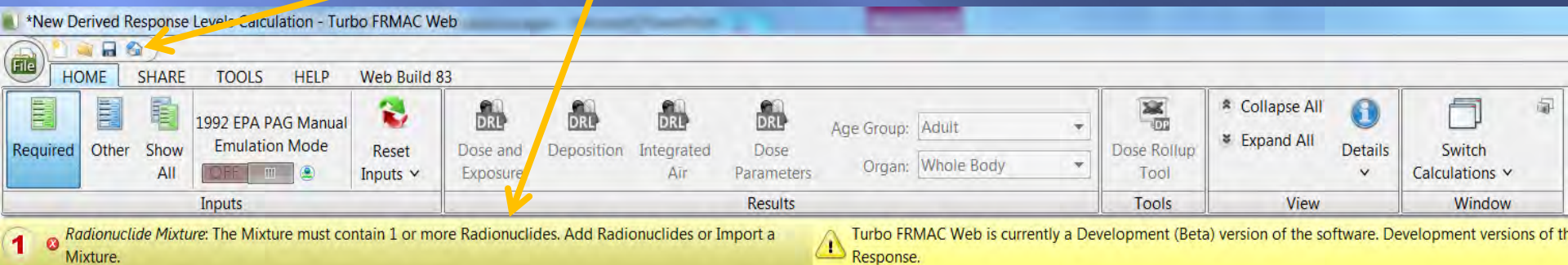
Copy from Existing
Make a copy of a saved Calculation to get started.



Turbo FRMAC General Layout

Ribbons and Tabs

- Controls calculations
- Allows movement to other work options
- Provides any error messages





Turbo FRMAC General Layout

- Buttons
 - Required Inputs
 - Other Inputs
- Panels
 - Individual data

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

Required Inputs

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

Radionuclide Mixture

Name: Unknown

Description:

Type of Measurement

☒ Activity per Area

☐ Mass per Area

The Mixture's Physical Form partitioning and Deposition Velocities will be adjusted for the selected Mixture Type.

Known Mixture Values

What values do you know for the Mixture?

☒ Activity per Area

☐ Integrated Air Concentration

☐ Both

'Integrated Air Concentration' values will be calculated using the 'Deposition Velocity'.

Add Radionuclide:

Search...

Import Export & Email Fill Age Scale Options

Physical Form Radionuclide Activity per Area Integrated Air Concentration Deposition Velocity Particle Size Distribution

0 parents, 0 daughters, 0 total

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

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

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



Features → Main Window

Clicking the button brings the panel into viewing area

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

Required Inputs

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

Radionuclide Mixture

Name: Unknown

Description:

Type of Measurement

Generic ☒ Activity per Area ☐ Mass per Area

The Mixture's Physical Form partitioning and Deposition Velocities will be adjusted for the selected Mixture Type.

Known Mixture Values

What values do you know for the Mixture?

☒ Activity per Area ☐ Integrated Air Concentration ☐ Both

'Integrated Air Concentration' values will be calculated using the 'Deposition Velocity'.

Add Radionuclide:

Search...

Physical Form Radionuclide Activity per Area Integrated Air Concentration Deposition Velocity Particle Size Distribution

0 parents, 0 daughters, 0 total

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

$[-4.86\text{E}303, 4.86\text{E}303]$ $[-4.86\text{E}303, 4.86\text{E}303]$ $[-\infty, \infty]$

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



Features → Main Window

Once the user provides required data, calculation buttons are “active”

*New Derived Response Levels Calculation - Turbo FRMAC

File HOME SHARE TOOLS HELP

Required Other Show All 1992 EPA PAG Manual Emulation Mode OFF Reset Inputs

DRL Dose and Exposure DRL Deposition DRL Integrated Air DRL Dose Parameters Age Group: Adult Organ: Whole Body

Dose Rollup Tool Collapse All Expand All Search Details Switch Calculations

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

Required Inputs

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

Radionuclide Mixture

Name: Cs-137

Description:

Type of Measurement

Generic Activity per Area Mass per Area

The Mixture's Physical Form partitioning and Deposition Velocities will be adjusted for the selected Mixture Type.

Known Mixture Values

What values do you know for the Mixture?

Activity per Area Integrated Air Concentration Both

'Integrated Air Concentration' values will be calculated using the 'Deposition Velocity'.

Add Radionuclide:

Search...

Import Export & Email Fill Age Scale

Physical Form	Radionuclide	Activity per Area	Integrated Air Concentration	Deposition Velocity	Particle Size Distribution
P	^{137}Cs	10.0	3.33E3	3.00E-3	Mono 100%
	$^{137\text{m}}\text{Ba}$	9.46	3.15E3	3.00E-3	Mono 100%

1 parent, 1 daughter, 2 total

μCi / m^2 (μCi · s) / m^3 m / s

[0.0, 1.74E29] [0.0, 1.74E29] [0.0, 100]



Features → Results

Calculation completed for all radionuclides and for all age groups

*New Derived Response Levels Calculation - Turbo FRMAC

File HOME SHARE TOOLS HELP

Required Other Show All 1992 EPA PAG Manual Emulation Mode OFF ON Reset Inputs

Dose and Exposure DRL Deposition Integrated Air Dose Parameters Age Group: Adult Organ: Adult

Dose Rollup Tool Collapse All Expand All Search Details Switch Calculations

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

Deposition Results

- Alpha DRLs
- Beta DRLs
- Radionuclide-Specific DRLs

Alpha DRLs

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

Early Phase	First Year	Second Year	Fifty Year	User Defined
N/A	N/A	N/A	N/A	N/A

Alpha Units: $\mu\text{Ci}_{\text{alpha}}$ / m^2

Beta DRLs

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

Early Phase	First Year	Second Year	Fifty Year	User Defined
1.46E3	41.6	12.5	6.57	1.72E4

Beta Units: $\mu\text{Ci}_{\text{beta}}$ / m^2

Radionuclide-Specific DRLs

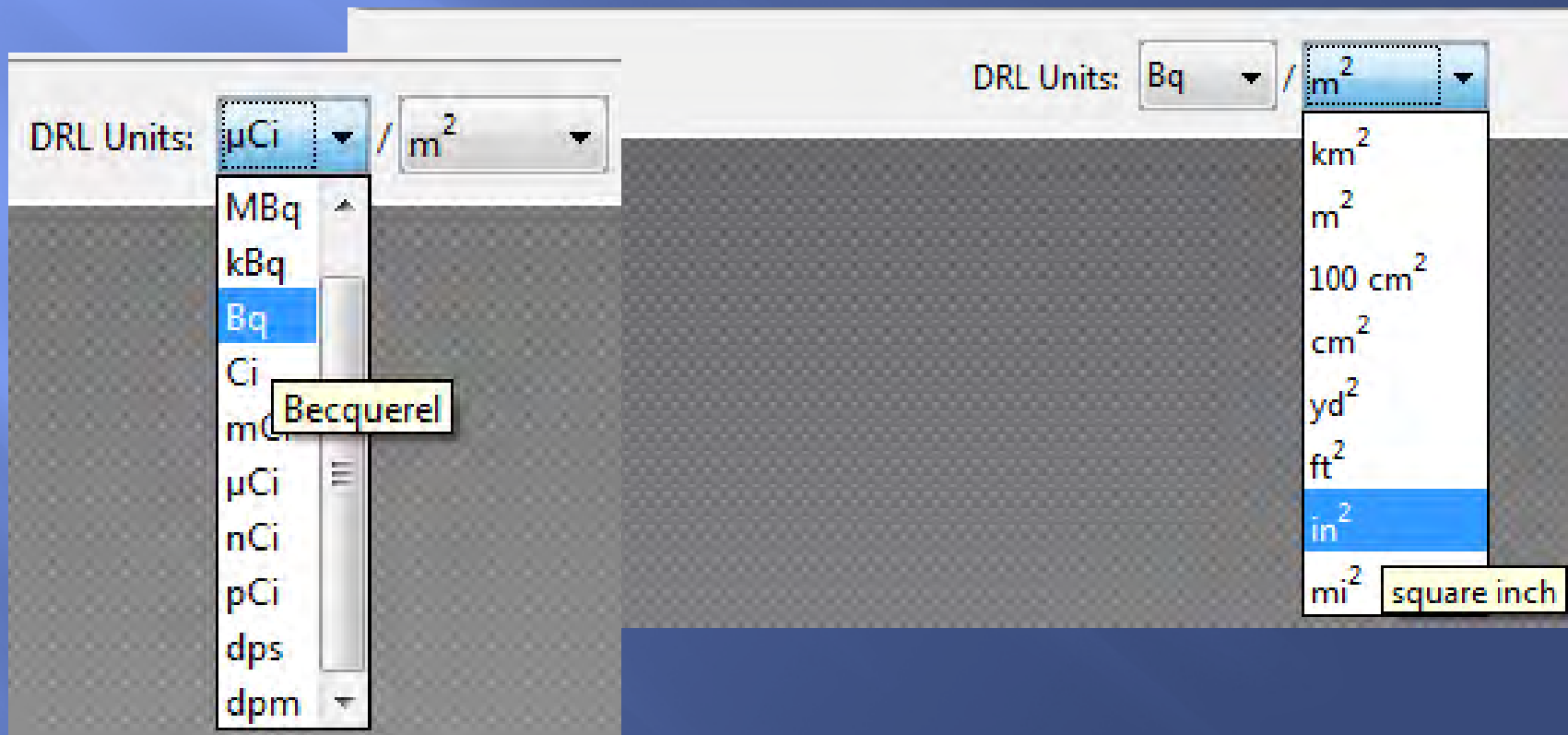
Whole Body values are displayed for **Adult** for a **Chronic** Commitment Period.

Radionuclide	Physical Form	Early Phase	First Year	Second Year	Fifty Year	User Defined
$^{137\text{m}}\text{Ba}$	P	1.38E3	39.4	11.8	6.22	1.62E4
^{137}Cs	P	1.46E3	41.6	12.5	6.57	1.72E4



Features → Results

Units can be converted as needed





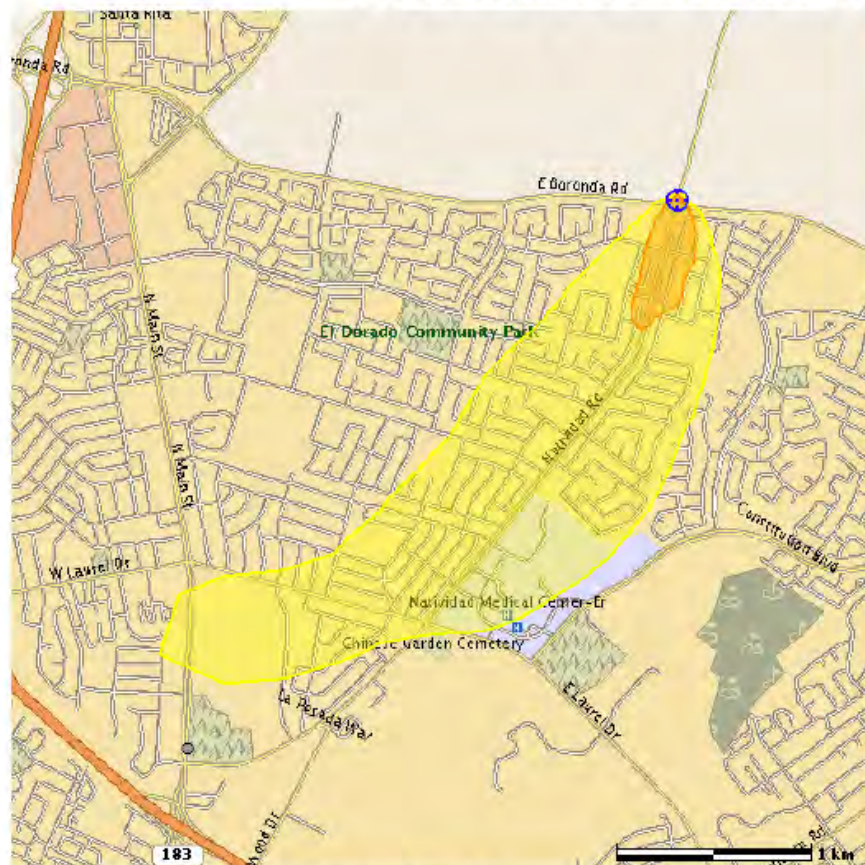
Example for Demonstration Only

Automated Report: Testing
(36.7158, -121.623)
RDD Release at 30 Jun 2011 13:00 UTC

Predicted Evacuation and Sheltering Areas - Most Limiting Criteria

The Whole Body Dose is the most limiting of the EPA Guide criteria

Avoidable Dose - Applicable 12 hr after start of release



- Shelter of entire population warranted, often followed by a delayed, deliberate evacuation. Those already outdoors should be removed from the area (exceeds 5 rem). Estimated Population: 360 Area: 0.1 km² Extent: 0.7 km**
- Evacuation or sheltering normally initiated (1 to 5 rem). Estimated Population: 10,300 Area: 2.7 km² Extent: 3.6 km**

Notes:

- EPA's Early Phase Guides provide separate criteria to limit dose to both the whole body and the thyroid. Separate predictions of the affected area were compared based on each criteria.
- The Whole Body Dose criterion is the most limiting in this case.
- Protective actions are normally based on the most limiting case.
- Prompt evacuation and/or sheltering reduces radiation dose and cancer risk. Sheltering-in-place may be more protective than evacuation while the radioactive cloud is present.
- Protective actions are only based on dose that can be avoided.
- Prediction excludes dose received before 01 Jul 2011 01:00 UTC.

Assumptions:

- Areas shown are model predictions based on an estimated release of airborne radioactivity, but no measurements yet available.
- Avoidable dose predicted from 12 hr to 108 hr after release start.
- Dose predicted for maximally exposed adult externally exposed to radiation from contamination on the ground and inhalation of resuspended contaminated dust. Also includes dose due to external exposure from and inhalation of the radioactive cloud, if present.

Briefing Product for Public Officials
Produced: 17 May 2013 21:56 UTC
Check for updates

Technical Details: CMHT
Advice & Recommendations: A-Team

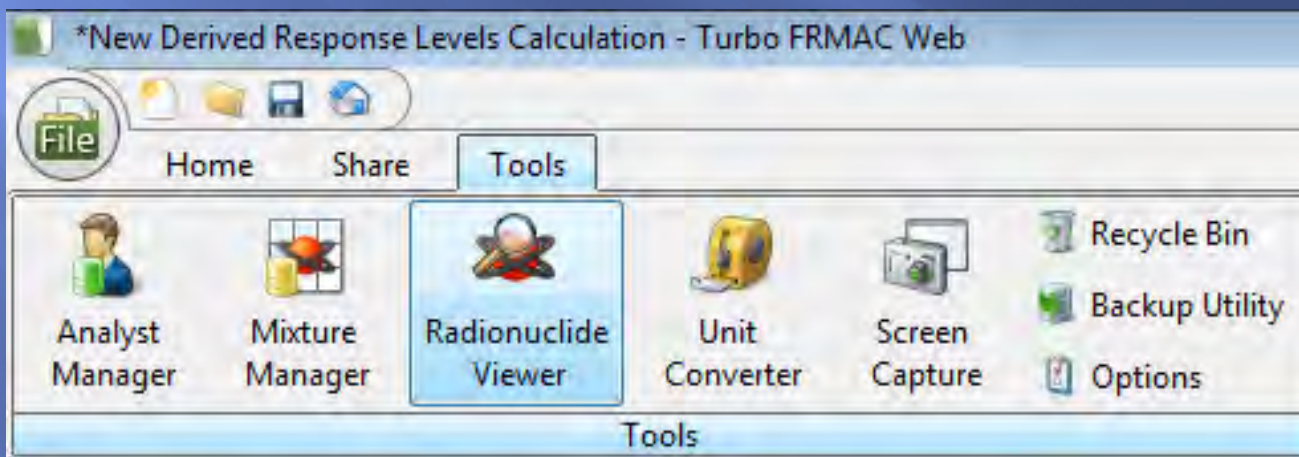
Example for Demonstration Only

page 1 of 3



Radionuclide Viewer

- Displays Full Radionuclide Decay Chain
- Displays basic nuclide data
 - Half Life
 - Decay mode
- Provides access to Dose Coefficients for each nuclide





Radionuclide Viewer

View the decay chain, dose coefficients, and other properties of Radionuclides.

Radionuclides

View Options

ICRP Guidance: ICRP 60...

Age: Adult

Commitment Period: Chronic

Instrument Threshold: 70 keV...

Select Radionuclide

Filter: Show All

Search: cs

- Cs-125
- Cs-126
- Cs-127
- Cs-128
- Cs-129
- Cs-130
- Cs-131
- Cs-132
- Cs-134
- Cs-134m
- Cs-135
- Cs-135m
- Cs-136
- Cs-137
- Cs-138

Decay Properties: Cs-137

Columns

Show Legends

Radionuclide	Half-Life	Decay Mode	Decay Constant	Branch Factor	Specific Activity	Fire Release Fraction	Total Emitted Alpha Energy	Total Emitted Beta Energy	Total Emitted Photon Energy
137Cs	1.10E4 B-		6.33E-5	N/A	8.71E10	1.00E-2	0.0	1.87E2	0.0
137mBa	1.77E-3 IT		3.91E2	0.946	5.38E17	1.00E-2	0.0	65.1	0.596

d

d⁻¹

Fraction

μCi

/

kg

Fraction

MeV

keV

MeV

Dose Coefficients

Cs-137 Stochastic Inhalation Dose Coefficients

Dose Coefficients

External

Surface

1 cm Soil Depth

5 cm Soil Depth

15 cm Soil Depth

Infinite Soil Depth

Air Submersion

Water Immersion

Inhalation

Ingestion

Inhalation

Organ	Dose Coefficient
Adrenal	17.6
Bone Surface	17.3
Brain	14.8
Breasts	14.1
Kidneys	16.9
Liver	17.1
Lower Large Intestine	20.9
Lung	16.0
Muscle	15.8
Ovaries	18.0
Pancreas	18.1
Red Marrow	16.5
Skin	13.5
Small Intestine	17.6
Spleen	16.9
Stomach	16.5
Testes	15.8
Committed Effective Dose	17.3

mrem

μCi

ICRP Guidance: ICRP 60

Age: Adult

Commitment Period: Chronic

View Particle Sizes for:

☒ Compound Distribution

☐ Vapor or Gas

Compound Distribution

View/Edit Distributions...

Distribution Summary:

1 Monodispersed

Lung Clearance Type

Maximum

Fast (F) - ICRP Recommended

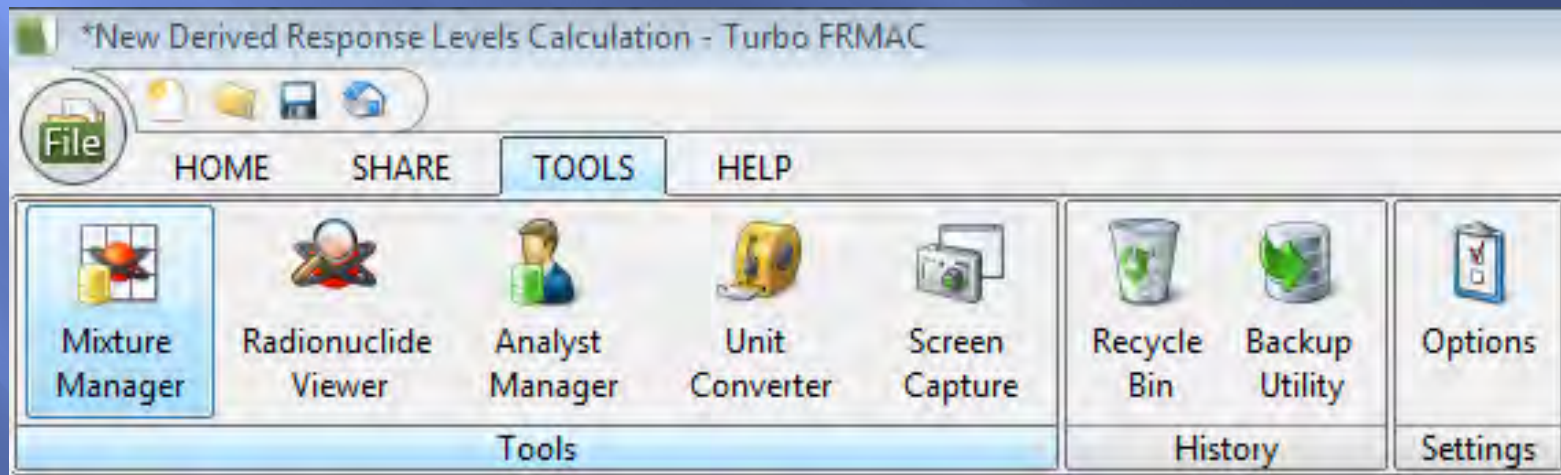
Medium (M)

Slow (S)



Radionuclide Mixture Manager

- Allows User to Create/Save/Export/Import Custom Mixtures
- User may select Pre-determined Mixtures





Radionuclide Mixture Manager

Mixture Manager

Home Share Tools

Create: New Mixture, New Uranium Enriched Mixture, New Folder

Mixture: Edit, Rename, Delete, Duplicate, Move, Age Mixture, Details

Folder: Rename, Delete, Select

Report: Generate Report

Radionuclide Mixtures

- Aged Fission Product
- Nuclear Detonation
- Nuclear Power Plant**
- Nuclear Weapon
- Other
- Plutonium
- Radiological Thermal Generator
- Training Mixtures
- Uranium Enriched

Nuclear Power Plant | Click below to view a Mixture in the 'Nuclear Power Plant'

- ☐ [Accident 1 hour\(s\) After Shutdown](#)
- ☐ [Accident 12 hour\(s\) After Shutdown](#)
- ☐ [Accident 15 day\(s\) After Shutdown](#)
- ☐ [Accident 24 hour\(s\) After Shutdown](#)
- ☐ [Accident 3 day\(s\) After Shutdown](#)
- ☐ [Accident 30 day\(s\) After Shutdown](#)
- ☐ [Accident 6 hour\(s\) After Shutdown](#)
- ☐ [Accident 7 day\(s\) After Shutdown](#)
- ☐ [Inventory At Time of Accident](#)



Turbo FRMAC

- Turbo FRMAC has been designed for Windows 7 and is compatible with Windows Vista, 7, 8 and 10
- Compatible with Mac OS 10.6 or newer.
- Minimum 2 GHz Pentium 4 Processor
 - Recommended: Dual- or Quad-Core or higher
- Minimum 2 GB RAM Memory
 - Recommended: 4 GB RAM or higher
- Minimum 15 GB Free Disk Space
 - Recommended: 25 GB Free or higher
- Minimum 1024 x 768 Screen Resolution
 - Recommended: 1280 x 1024 or higher
- Other Software
 - MS Excel 2007 or newer (for special data export capabilities)
 - MS Outlook 2007 or newer (for built-in email attachment support)
 - MS PowerPoint 2007 or newer (for briefing products)
 - MS Word 2007 or newer (for report generation)
 - Adobe Acrobat Reader (for viewing related documents)



Questions?

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