

Documentation for the Human Health Impact Module of the Multimedia Environmental Pollutant Assessment System (MEPAS)

Compiled from Former Publications [PNNL-SA-32283](#) and [PNNL-10523](#)

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1.0 Introduction

This documentation provides information on a component of the Multimedia Environmental Pollutant Assessment System (MEPAS), including requirements, design and specifications or formulations, and quality assurance and testing. MEPAS is an integrated impact assessment software comprising physics-based fate and transport models of air, soil, and water media. Outputs are estimates of exposures and health risk assessments for radioactive and hazardous pollutants.

MEPAS simulates the release of contaminants from a source; transport through the air, groundwater, surface water, and/or overland pathways; and transfer through food chains and exposure pathways to the exposed individual or population. For human health impacts, risks are computed for carcinogens and hazard quotients for noncarcinogens.

MEPAS is implemented on a desktop computer with a user-friendly interface that allows the user to define the problem, input the required data, and execute the appropriate models for both deterministic and probabilistic analyses.

The various MEPAS components were originally designed as a suite of tools. They have been specifically revised as objects for inclusion in the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES), which is a software platform that allows for the linking of various modules into complete emission, transport, and exposure assessment systems ([Whelan et al. 1997](#). PNNL-11748).

Portions of this documentation may have been previously issued in reports from the Pacific Northwest National Laboratory (PNNL), operated by Battelle for the U.S. Department of Energy. All PNNL reports are issued a tracking number. Multiple numbers on the title page of this documentation indicate the numbers of these previous reports.

This documentation can be used by software engineers and testers to ensure that each component functions properly. The information can also be used by analysts and managers to better understand the component's use within FRAMES.



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Requirements of the MEPAS Human Health Impact Module

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This section provides an overall summary of the requirements for the MEPAS Human Health Impact Module. The MEPAS Human Health Impact Module calculates time-varying, contaminant (chemical and radionuclide) health impacts, as well as dose equivalence for radionuclides, as a function of exposure pathway and receptor. The following table shows the exposure pathways addressed by this module as a function of the transport media. Detailed input, output, and scientific requirements are described in the section that follows.

MEPAS Human Health Impact Module Exposure Pathways for Each Transport Medium

Exposure Pathway	Transport or Source Medium			
	Ground Water	Surface Water	Atmosphere	Soil
Ingestion of drinking water	Yes	Yes	No	No
Dermal contact with water while showering	Yes	Yes	No	No
Inadvertent ingestion of water while showering	Yes	Yes	No	No
Ingestion of leafy vegetables	Yes	Yes	Yes	Yes
Ingestion of other vegetables	Yes	Yes	Yes	Yes
Ingestion of meat	Yes	Yes	Yes	Yes
Ingestion of milk	Yes	Yes	Yes	Yes
Ingestion of fin fish	No	Yes	No	No
Ingestion of shellfish	No	Yes	No	No
Inadvertent ingestion of water while swimming	No	Yes	No	No
Dermal contact with water while swimming	No	Yes	No	No
Dermal contact with sediment during shoreline use	No	Yes	No	No
Inadvertent ingestion of sediment during shoreline use	No	Yes	No	No
Inadvertent ingestion of soil	No	No	Yes	Yes
Dermal contact with soil	No	No	Yes	Yes
Indoor inhalation of volatile chemicals released from shower water	Yes	Yes	No	No
Indoor inhalation of volatile chemicals released from other domestic water uses	Yes	Yes	No	No
Inhalation of outdoor air from a passing plume	No	No	Yes	No
Inhalation of resuspended soil particles	No	No	Yes	Yes
External exposure to radionuclides while swimming	No	Yes	No	No
External exposure to radionuclides while boating	No	Yes	No	No
External exposure to radionuclides in sediment during shoreline use	No	Yes	No	No
External exposure to radionuclides in soil	No	No	Yes	Yes
External exposure to radionuclides in outdoor air from a passing plume	No	No	Yes	No
Measured concentrations in foods (special foods)	n/a	n/a	n/a	n/a

The MEPAS Human Health Impact Module will

- G1 - compute time-varying, contaminant (chemical and radionuclide) health impacts for all exposure pathways listed in Table 2.1
- G2 - allow up to 25 constituents to be considered in a scenario
- G3 - operate under Windows 95, 98, 2000, NT, ME, and XP and have a user-friendly module user interface (MUI) with a standard Windows look and feel
- G4 - meet the module specifications for the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES).

Input Requirements of the MEPAS Human Health Impact Module

Data needed to compute human receptor health impacts are obtained from three sources:

- The boundary conditions (i.e., time-varying, exposure medium concentrations or dose equivalence for the external radiation exposure pathways, and time-varying, intake rates for the remaining pathways) are obtained from the previous module in the scenario.
- The health impact control parameters for chemicals and radionuclides, and the health effects conversion factors for radionuclides, are obtained from the user through the MUI.
- Reference doses, dose conversion factors, and slope factors are obtained from a chemical property database.

The boundary conditions are communicated to the module through the Receptor Intake File (RIF). The input data supplied through the MUI is communicated to the model through the Global Input Data file (GID) and the model pre-processor. The GID file is also used to store the reference doses and conversion factors.

There are some general requirements associated with the MUI, which are

- M1 - The MUI will operate in Windows 95, 98, 2000, NT, ME, and XP and will have a standard Windows look and feel.
- M2 - The MUI will have online help in an HTML format that provides users with an easy-to-understand description of all input parameters required.
- M3 - The MUI will provide users with a choice of units for all input parameters with associated dimensions.
- M4 - The MUI will include a reference feature in which the source of the specified value for each input item can be referenced if desired.
- M5 - The MUI will convert the dimensions of user input data values into the units needed by the model and will always display the exact value and units in which the user originally entered each input data item.
- M6 - The MUI will show the range of values allowed for each input data item, when the cursor is positioned on that item, as a scrolling message at the bottom of the screen. When an out-of-range value is entered in a field, the MUI will indicate this by a red background in the input field and an error message in addition to the allowed range message. Data input values within range are indicated by a green field background.

Specific input requirements for the MUI are as follows:

- I1 - for radionuclide exposures, allow the user to select from the following cancer risk evaluation methods: A) International Council on Radiation Protection and Measurements (ICRP) dose and risk factors or B) U.S. Environmental Protection Agency (EPA) HEAST radionuclide slope factors.
- I2 - when the ICRP dose and risk factors are to be used, allow the user to supply thickness of soil layer and dry bulk density of soil layer (for the soil that receives contamination from air deposition).
- I3 - for chemical exposures, allow the user to select lifetime cancer incidence or hazard index as endpoints in the analysis. When the user selects evaluation of hazard index results, allow the user to specify a threshold value below which results are reported as zero. (Note: regardless of what the user selects, the analysis will still be limited to evaluations possible based on the values provided in the input file [*].RIF). For example, the input file may only contain intake rates for hazard index evaluations, in which case the Human Health Impact Module will not be able to generate cancer risk results).
- I4 - allow the user to limit the analysis to toxicity values of specific quality, as defined by the source of the values available in the MEPAS database. The analysis can be only for chemicals having toxicity values from the EPA IRIS and HEAST databases, or the analysis can include all toxicity values provided.

The data obtained from the RIF by the MEPAS Human Health Impact Module, and required for the module to perform its computations, include average dose equivalence for the external radiation exposure to outdoor air pathway, average exposure medium concentrations for the other external radiation pathways, or average intake rates for the remaining pathways, for a specified time interval, contaminant (including progeny), and exposure location as contained in the RIF. Multiple exposure locations are allowed only for atmospheric transport analysis (I5).

As needed, the following data are obtained from the chemical properties database:

- reference doses for noncarcinogenic chemicals
- slope factors for carcinogenic chemicals
- slope factors and dose conversion factors for radionuclides.

Output Requirements of the MEPAS Human Health Impact Module

The MEPAS Human Health Impact Module has the following output requirements:

- O1 - produce a Health Impacts File (HIF) that contains time-varying, average contaminant risk or hazard index for each exposure pathway in accordance with the FRAMES data file specifications
- O2 - produce a list file (*.HLS file) in ASCII format that documents the data actually read in by the model.

The following data is output to the HIF:

- time-varying, average cancer incidence risk for each carcinogenic chemical contaminant, for each exposure pathway, time interval, and exposure location - multiple exposure locations are allowed only for the atmospheric transport analysis.
- time-varying, average hazard index for each noncarcinogenic chemical contaminant, for each exposure pathway, time interval, and exposure location - multiple exposure locations are allowed only for the atmospheric transport analysis.
- time-varying, average cancer incidence risk, and/or fatal cancer risk, and/or risk of cancer plus severe hereditary effects, and/or radiation dose equivalence for each radionuclide contaminant, for each exposure pathway, time interval, and exposure location - multiple exposure locations are allowed only for the atmospheric transport analysis.

Scientific Requirements of the MEPAS Human Health Impact Module

The scope of the human health impact analysis is determined by the modules that are connected to the exposure module (e.g., atmospheric transport and groundwater), and by the selections the user makes in the Human Health Impact Module MUI. The mathematical formulations for this module are provided in [Strenge and Chamberlain, 1995](#) (PNL-10523) and included in this documentation (see [Contents](#)).

Scientific requirements for the Human Health Impact Module are as follows:

- S1 - use cancer incidence risk as the health impact measure for carcinogenic chemicals, determined by multiplying the pollutant intake by a predetermined relationship between intake and cancer incidence risk (i.e., a slope factor). A value of zero will be reported for chemicals that do not have a slope factor value for an exposure pathway.
- S2 - use the hazard quotient as the health impact measure for noncarcinogenic chemicals, determined by dividing the pollutant intake by a predetermined reference dose (an estimate of a daily intake rate that an average individual can tolerate without the risk of adverse health consequences during a lifetime). A value of zero will be reported for chemicals that do not have a reference dose for an exposure pathway.
- S3 - calculate dose equivalence for radionuclides by multiplying the pollutant intake by a factor relating intake to dose equivalence (i.e., a dose conversion factor) for ingestion, inhalation, and dermal contact exposure pathways.
- S4 - calculate dose equivalence for radionuclides by multiplying the pollutant concentration in the exposure medium by a factor relating the exposure medium concentration to dose equivalence (i.e., a dose conversion factor) for the external radiation exposure pathways (except for outdoor air).
- S5 - determine the cancer incidence risk for the ingestion, inhalation, and external exposure to soil pathways for radionuclides by multiplying the pollutant intake by a predetermined relationship between intake and cancer incidence risk (i.e., a slope factor) or by multiplying dose equivalence by the appropriate conversion factor relating dose equivalence to risk (i.e., a health effects conversion factor), as indicated by the user.
- S6 - determine risk (cancer incidence risk and/or fatal cancer risk and/or risk of cancer plus severe hereditary effects) for all other exposure pathways and risk output combinations not covered under requirements above for radionuclides by multiplying dose equivalence by the appropriate conversion factor relating dose equivalence to risk (i.e., a health effects conversion factor).

Other References

- *Concepts of a Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)*. ([Whelan et al. 1997](#), PNNL-11748).

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Design of the MEPAS Human Health Impact Module

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The MEPAS Human Health Impact Module calculates time-varying, contaminant (chemical and radionuclide) health impacts, as well as dose equivalence for radionuclides, as a function of exposure pathway and receptor. A full description of the design parameters, as well as scientific formulations for the various models, can be found in [Streng and Chamberlain, 1995](#) (PNL-10523) and accessed online by following this link:

- [Formulations for the MEPAS Human Health Impact Module](#).

Additional design information for the Human Health Impact Module can be found in

- [Human Health Impact Module Help files](#)
- Specifications for the Human Health Impact Module for FRAMES 1.x
 - Input Specifications*
 - [RIE-Receptor Intake File](#)
 - Output Specifications*
 - [ATQ-Health Impacts File](#)
- [dictionary files](#) for the Human Health Impact Module for FRAMES 2.x.



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Quality Assurance and Testing for the MEPAS Human Health Impacts Module

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The Human Health Impacts Module was developed under a quality assurance (QA) program that looked at the software life cycle: requirements analysis, design, programming, modification, testing, and implementation. Quality is defined as the ability of the software to meet client needs. Meeting client needs starts with a shared understanding of how the software must perform and continues throughout the software life cycle through attention to details.

The program was designed to be compatible with similar processes used by our clients. For example, our QA process compares favorably with that in the U.S. Environmental Protection Agency Directive 2182, *System Design and Development Guidance* (EPA,1997, Directive 2182). It also compares favorably with the Office of Civilian Radioactive Waste Management's *Quality Assurance Requirements and Description, Supplement I, Software* (OCRWM,1995).

Part of the QA program involves testing each component to ensure that it satisfies its requirements. The [requirements](#) section of this documentation provides a list of requirements for the MEPAS Human Health Impacts Module. A test plan was developed with test cases that addressed these requirements. The following table shows how these requirements were addressed in testing.

Testing Matrix for the MEPAS Human Health Impacts Module

Requirement	Test Case								
	1	2	3	4	5	6	7	8	9

1	Y	-	-	-	-	-	-	-	-
2	Y	-	-	-	-	-	-	-	-
3	Y	-	-	-	-	-	-	-	-
4	Y	-	-	-	-	-	-	-	-
5	Y	-	-	-	-	-	-	-	-
6	Y	-	-	-	-	-	-	-	-
7	Y	-	-	-	-	-	-	-	-
8	Y	Y	-	-	Y	-	-	-	-
9	Y	Y	-	-	-	-	-	-	-
10	Y	-	-	-	-	-	-	-	-
11	Y	-	-	-	-	-	Y	-	-
12	Y	-	-	-	-	-	-	Y	-
13	Y	-	-	-	-	-	-	-	-
14	-	Y	-	-	-	-	-	-	-
15	-	Y	Y	Y	-	Y	-	-	-
16	-	Y	-	-	-	-	-	-	-
17	-	Y	Y	Y	-	Y	-	-	-
18	-	Y	Y	Y	-	Y	-	-	-
19	-	Y	Y	Y	-	Y	-	-	-
20	-	Y	Y	Y	-	Y	-	-	-
21	-	Y	Y	Y	-	Y	-	-	-
22	-	Y	Y	Y	-	Y	-	-	-
23	-	-	-	-	-	-	-	-	Y

Since test packages can be affected by coding changes in different versions, the tests (including the documents they generate) are packaged with the FRAMES Install.

For additional information on the QA program, including testing, see the following documents:

- *An Approach to Ensuring Quality in Environmental Software* (Gelston et al.,1998, PNNL-11880)

