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

Compiled from Former Publications PNNL-SA-32285 and PNL-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 Intake Module

This section provides an overall summary of the requirements for the MEPAS Human Intake Module. For all but the external radiation exposure pathways, this module calculates chemical and radionuclide intakes for individuals at the point of exposure or contact with contaminated media (e.g., water, soil, air, food crops, meat, or milk). For the external radiation exposure to soil or water pathways, the exposure medium concentration is computed and provided as output. 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 sections that follow.

Table 2.1. MEPAS Intake Module Exposure Pathways for Each Transport Medium

Exposure Pathway	Transport or Source Medium			
	Groundwater	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

The MEPAS Human Intake module will:

- G1 - output the exposure medium concentrations for external radiation exposure to air, soil or water pathways, dose equivalence for the external radiation exposure to outdoor air, or chemical and radionuclide intake rates (average mass of chemical per unit body weight per unit time during the exposure period, or total radionuclide activity intake during the exposure period) for the remaining exposure pathways in Table 1. These computations are based on exposure medium chemical and radionuclide concentrations for each time period in a set of exposure duration time periods.
- 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 Intake Module

Data needed to compute intake rates (or to provide exposure medium concentrations or dose equivalence for the external radiation pathways) are obtained from two sources. The previous module in the scenario (i.e., an exposure module) provides the boundary conditions (i.e., contaminant concentrations in the exposure medium), which are communicated to the module through the Exposure Pathway File (EPF). The user through the MUI provides media intake rates (e.g., drinking water ingestion rate, air inhalation rate) and other receptor characteristics, which are communicated to the model through the Global Input Data (GID) file and the model pre-processor.

General requirements associated with the MUI 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 by the MUI.
- M3 - The MUI will provide users with a choice of units for all input parameters having dimensions associated with them.
- 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 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 a scrolling error message in addition to the allowed range message. Data input values within range are indicated by a green field background.

The MUI must also allow the user **(M6)** to input the following data to define the exposure scenario:

- Body weight for the exposed individual and the exposure duration to be applied to all exposure pathways.
- The model to be used to evaluate dermal absorption for organic constituents. The options are to use the U.S. Environmental Protection Agency (EPA) dermal absorption model (a non-linear function of contact time and chemical properties) or the linear dermal absorption model (absorption proportional to permeability constant and contact time). The linear dermal absorption model is the only option available for inorganic chemicals and radionuclides.
- The drinking water intake rate for groundwater and surface water used as a source of domestic water.

The following data are obtained from the EPF by the MEPAS intake module and are required for the module to perform its computations:

- Average exposure medium concentration for each exposure pathway (except external radiation exposure to outdoor air within a passing plume), specified time interval, contaminant (including progeny), and exposure location, contained in the EPF. Multiple exposure locations are allowed only for the atmospheric transport analysis **(M7)**.
- Average dose equivalence for the external radiation exposure to outdoor air within a passing plume.

The MUI must also allow the user to define or modify the following parameters **(M8)**

:

- the drinking water annual exposure frequency factor (fraction of days per year that drinking water ingestion occurs)
- thickness of skin layer (used only for EPA dermal exposure model for organic chemicals)
- shower daily frequency factor
- shower event duration
- dermal contact skin area exposed while showering
- inhalation rate while showering or while indoors for exposure to constituents released from domestic water
- rate of water ingestion for inadvertent ingestion while showering
- shower dermal contact annual exposure frequency factor
- shower inadvertent ingestion annual exposure frequency factor
- shower or indoor air inhalation annual exposure frequency factor.

The MUI will also allow the user to define/modify the following parameters related to shoreline exposure (for the surface water transport pathway only)**(M9)**:

- duration of one shoreline exposure event
- daily frequency of shoreline exposure events
- ingestion rate of shoreline sediments
- shore width factor for external shoreline radiation exposure
- area of skin contacted during shoreline exposure events
- shoreline dermal contact annual exposure frequency factor
- shoreline sediment ingestion annual exposure frequency factor
- shoreline external exposure annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to swimming exposure pathways (for the surface water transport pathway only)**(M10)**:

- thickness of skin layer (used only for EPA dermal exposure model for organic chemicals)
- duration of one swimming event
- water ingestion rate while swimming
- daily frequency of swimming events
- area of skin exposed while swimming
- swimming inadvertent ingestion annual exposure frequency factor
- swimming dermal contact annual exposure frequency factor
- swimming external exposure annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to boating exposure pathway (for the surface water transport pathway only)**(M11)**:

- duration of one boating event
- daily frequency of boating events
- boating geometry factor for external exposure
- boating external exposure annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to aquatic food exposure pathways (for the surface water transport pathway only)**(M12)**:

- ingestion rate of fin fish
- ingestion rate of shellfish
- fin fish ingestion annual exposure frequency factor
- shellfish ingestion annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to soil exposure pathways (for the atmospheric transport and measured soil pathways only)**(M13)**:

- area of skin exposed during soil contact events
- soil adherence factor for skin contact events
- daily frequency of skin contact events
- soil skin contact events annual exposure frequency factor
- soil ingestion rate
- soil ingestion annual exposure frequency factor
- thickness of measured soil contamination layer
- density of measured soil contamination layer.

The MUI will allow the user to define/modify the following parameters related to air exposure pathways (for the atmospheric transport measured soil pathways only)**(M14)**:

- inhalation rate for exposure to contaminated air
- inhalation rate for the resuspension pathway
- air inhalation annual exposure frequency factor
- soil resuspension factor annual exposure frequency factor
- external air radiation dose annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to external exposure to contaminated soil (for the atmospheric transport measured soil pathways only)**(M15)**:

- fraction of time spent indoors
- fraction of time spent outdoors
- shielding factor for time spent indoors
- shielding factor for time spent outdoors
- daily exposure time to external ground contamination
- external ground radiation exposure annual exposure frequency factor.

The MUI will allow the user to define/modify the following parameters related to terrestrial food products (value are applied to all four transport pathways)**(M16)**:

- ingestion rate of leafy vegetables
- ingestion rate of other vegetables
- ingestion rate of meat
- ingestion rate of milk
- leafy vegetable ingestion annual exposure frequency factor
- other vegetable ingestion annual exposure frequency factor
- meat ingestion annual exposure frequency factor
- milk ingestion annual exposure frequency factor.

Output Requirements of the MEPAS Human Intake Module

The MEPAS intake module has the following output requirements:

- O1 - produce a Receptor Intake File (RIF) that contains time-varying, average radiation dose equivalence for the external radiation exposure to outdoor air pathway (if input is in terms of radiation dose, otherwise output is in terms of concentration), exposure medium concentrations for the other external radiation exposure pathways, or chemical and radionuclide intake rates for the remaining exposure pathways in Table 1, in accordance with the FRAMES data file specifications
- O2 - produce a list file (*.RLS file) in ASCII format that documents the data actually read in by the model and summarizes intermediate calculation results such as summary intake factors
- O3 - allow multiple exposure locations only for the atmospheric transport analysis.

The data output to the RIF includes radiation dose equivalence for the external radiation exposure to outdoor air pathway, exposure medium concentration for the other external radiation exposure pathways, and chemical and radionuclide intake rates for the remaining exposure pathways in Table 1, for each exposure duration time period, constituent (including progeny), and exposure location.

Scientific Requirements of the MEPAS Human Intake Module

The scope of the intake analysis is determined by the modules that are connected to the exposure module (e.g., atmospheric transport or groundwater) and by the selections the user makes in the intake module MUI. The scientific formulations for this module are provided in Strenge and Chamberlain, 1995 (PNL-10523).

Scientific requirements for the intake module are as follows:

- S1 - calculate dermal absorption of organic chemicals from water using the U.S. Environmental Protection Agency (EPA) dermal absorption model or the linear absorption model as requested by the user, and as supporting chemical parameters are available in the database
- S2 - read the dose equivalence values or air concentrations, make adjustments for exposure frequency as necessary, and write the results to the RIF as radiation dose equivalence or air concentration for the external radiation exposure to outdoor air pathway
- S3 - calculate and write to the RIF the chemical intake rates evaluated for both non-carcinogenic effects and carcinogenic effects.

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 Intake Module

For all but the external radiation exposure pathways, the MEPAS Human Intake Module calculates chemical and radionuclide intakes for individuals at the point of exposure or contact with contaminated media (e.g., water, soil, air, food crops, meat, or milk). For the external radiation exposure to soil or water pathways, the exposure medium concentration is computed and output. For the external radiation exposure to outdoor air, the output is dependent on the input information provided. A full description of the design parameters, as well as scientific formulations for the various models, can be found in Strenge and Chamberlain, 1995 (PNL-10523) and accessed online by following this link:

- Formulations for the MEPAS Human Intake Module.

Additional design information for the Human Intake Module can be found in

- Human Intake Module Help files
- Specifications for the Human Intake Module for FRAMES 1.x
  Input Secifications
  - EPF-Exposure Pathway File

  Output Specifications
  - RIF-Receptor Intake File
- dictionary files for the Human Intake Module for FRAMES 2.x.

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Quality Assurance and Testing for the MEPAS Human Receptor Intake Transport Module

The Human Receptor Intake Transport 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 Atmospheric Transport 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 Atmospheric Transport Module

Requirement	Test Case						
---	1	2	3	4	5	6	7
1	Y	-	-	-	-	-	-
2	Y	-	-	-	-	-	-
3	Y	-	-	-	-	-	-
4	Y	-	-	-	-	-	-
5	Y	-	-	-	-	-	-
6	Y	-	-	-	-	-	-
7	Y	-	-	-	-	-	-
8	Y	-	-	-	-	-	-
9	Y	-	-	-	-	-	-
10	-	-	-	-	-	Y	-
11	-	Y	Y	Y	Y	-	-
12	-	Y	Y	Y	Y	-	-
13	-	-	-	-	Y	-	-
14	-	Y	-	-	-	-	-
15	-	-	-	-	-	-	Y
16	Y	Y	Y	Y	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)
