

**An Overview of the Multimedia Environmental
Pollutant Assessment System**

K. L. Michel

Environmental Restoration Division
P.O. Box 2003
Oak Ridge, Tennessee 37831-7298

Date Issued--June 1992

Prepared by
Health and Safety Research Division
Risk Analysis Section
Oak Ridge National Laboratory

Prepared for
U.S. Department of Energy
Office of Environmental Restoration and Waste Management
under budget and reporting code EW 20

MASTER

MARTIN MARIETTA ENERGY SYSTEMS, INC.
managing the

Oak Ridge K-25 Site
Oak Ridge Y-12 Plant
Oak Ridge National Laboratory
under contract DE-AC05-84OR21400

Paducah Gaseous Diffusion Plant
Portsmouth Gaseous Diffusion Plant
under contract DE-AC05-76OR00001

for the
U.S. DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ff

Author Affiliations

K. L. Michel is in Technical Applications in the Computing and Telecommunications Division, Martin Marietta Energy Systems, Inc.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CONTENTS

ABSTRACT	vii
1. INTRODUCTION	1
2. GENERAL	2
3. CONTAMINANT RELEASES	3
3.1 RELEASE INTO THE ATMOSPHERE	3
3.2 RELEASE FROM SOIL	4
3.3 RELEASE TO GROUNDWATER	4
3.4 RELEASE TO SURFACE WATER	5
3.5 DIRECT EXPOSURE	5
4. EXPOSURE PATHWAYS	6
5. HEALTH RISK INDEXES	7
5.1 DOSE CALCULATION	7
5.2 RISK CALCULATION	7
5.2.1 Risk for Radioactive Contaminants	8
5.2.2 Risk for Chemical Contaminants	8
5.3 PRELIMINARY HAZARD POTENTIAL INDEX CALCULATION	9
5.4 HAZARD POTENTIAL INDEX CALCULATION	10
5.5 HAZARD POTENTIAL INDEX SCORE EVALUATION	10
6. EXAMPLE APPLICATION OF MEPAS	12
6.1 DOSE CALCULATION	12
6.1.1 Drinking Water	13
6.1.2 Recreation	14
6.1.3 Fishing	16
6.2 RISK CALCULATION	17
6.3 PRELIMINARY HAZARD POTENTIAL INDEX CALCULATION	18
6.4 HAZARD POTENTIAL INDEX CALCULATION	19
7. CONCLUSION	20
REFERENCES	21
APPENDIX A. Input and Output Files Created by MEPAS	23
APPENDIX B. Example <i>HPI</i> Output File	27
APPENDIX C. Example <i>WAT</i> Output File	37

TABLES

1. Drinking water dose calculation values	14
2. Recreation dose calculation values	15
3. Swimming dose calculation values	16
4. Finfish ingestion dose calculation values	17
5. Risk for ^{137}Cs (radionuclide)	17
6. Risk for polychlorinated biphenyls (chemical carcinogen)	17
7. Risk for mercury (chemical noncarcinogen)	18
8. <i>PI</i> values for ^{137}Cs	18
9. <i>PI</i> values for polychlorinated biphenyls	19
10. <i>PI</i> values for mercury	19
11. <i>HPI</i> scores for example problem	19

ABSTRACT

This report describes the Multimedia Environmental Pollutant Assessment System (MEPAS) computer model designed by Pacific Northwest Laboratory for use in evaluating the health risks associated with U.S. Department of Energy (DOE) waste sites. This report has been prepared to provide DOE Oak Ridge Field Office personnel with a simplified explanation of MEPAS and an understanding of how MEPAS is used to quantify potential risks to human health. The scope and limitations of the MEPAS model are presented, and the possible contaminant release media and transport pathways are outlined.

The two main types of health indexes generated—the hazard potential index (*HPI*) and the maximum individual index are described; and calculations used to obtain these indexes are presented. Guidance on interpretation of the *HPI* is also included. Finally, the *HPI* calculations for 3 contaminants in a hypothetical environmental problem are demonstrated.

Appendix A contains a list of the input and output files created by MEPAS; Appendix B contains the *HPI* report for the example problem; and Appendix C is the WAT output file produced for the example problem. This report describes the MEPAS code version 2.1G, dated January 26, 1992, with reports revised April 12, 1992. Subsequent versions may contain modifications and enhancements not addressed in this report or values different than those used in the example.

1. INTRODUCTION

Pacific Northwest Laboratory (PNL) of Richland, Washington, developed the Multimedia Environmental Pollutant Assessment System (MEPAS) computer model for the U.S. Department of Energy (DOE) Office of Environment, Safety, and Health as a tool to evaluate the adverse health impacts of its waste sites and thus rank the sites for cleanup. This report summarizes MEPAS version 2.1G capabilities and the methodologies used to determine a health-risk-based score for environmental problems. This report has been prepared to provide DOE Oak Ridge Field Office personnel with a simplified explanation of MEPAS and an understanding of how MEPAS is used to quantify potential risks to human health.

The underlying methodology of MEPAS is known as the Remedial Action Priority System (RAPS). This methodology was developed in 1985 and 1986 by PNL with the intent of prioritizing hazardous and radioactive mixed waste disposal sites scientifically and objectively. RAPS and its mathematical formulations (Whelan et al. 1987) have been independently reviewed by technical authorities in the private and public sectors. In addition, the methodology has been tested at facilities where contaminant levels have been monitored in the environment, thus allowing comparison with model-simulated results (Whelan et al. 1989).

MEPAS uses mathematical algorithms to simulate the passage of chemical and radionuclide contaminants through environmental media to specified locations of potential food chain or human exposure. The model then evaluates the degree of exposure that the surrounding population receives and calculates the associated health risk. MEPAS produces two main indicators of risk for each environmental problem modeled: the maximum individual index (MII), based on individual exposure, and the hazard potential index (HPI), weighted by the number of people exposed. Environmental problems can, therefore, be ranked relative to other problems scored by the system.

The model is designed to run on any IBM® personal computer series machine having 640K RAM, a hard disk, and a printer. A math coprocessor will improve model speed and performance but is not required.

2. GENERAL

MEPAS is designed to be more comprehensive than the site-screening Environmental Protection Agency's (EPA's) Hazard Ranking System and less intensive than risk assessments conducted for remedial investigation/feasibility studies required by the Comprehensive Environmental Response, Compensation, and Liability Act. MEPAS is not intended to determine health risks caused by waste sites precisely but to estimate potential health-risk magnitude. The model does, however, require a considerable amount of data to define the contaminant release, to characterize the transport media, and to define the potential exposure locations and affected populations.

For accurate modeling, a user of MEPAS should have an extensive knowledge of the facility and the surrounding area, including awareness of site meteorology, geology, hydrogeology, soil characteristics, surface water usage, groundwater usage, surrounding population distribution, agriculture production distribution, and history of site activities. In addition, the MEPAS application guidance Volume 2 (Droppo et al. 1989b) supplies itemized, detailed instructions for determining MEPAS inputs, including tables, suggested values and ranges, and possible sources for obtaining required information. It is important that input data be accurate and consistently acquired so that site evaluations and comparisons are credible.

3. CONTAMINANT RELEASES

MEPAS evaluates the potential health risk contributed by individual waste areas within a facility. The source of the contaminant release is referred to in the model as a release unit (RU). For each RU in the facility, the release media, transport pathways, usage locations, and exposure pathways must be defined. Releases can be to air, surface soil (SS), groundwater (GW), or surface water (SW), or the release could be a direct exposure.

The following sections describe each possible contaminant release medium and the pathways through other environmental media which can be modeled. More information about terminology and defining a waste problem to the model can be found in *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance—Getting Started with MEPAS* (Buck et. al. 1989) and in the MEPAS application guidance Volume 1 (Droppo et. al. 1989a).

3.1 RELEASE INTO THE ATMOSPHERE

For a contaminant release to the atmosphere, the following pathways through different environmental media can be modeled.

- Pollutants remain in the air with some deposition to surface soil (RU > Air/SS).
- Pollutants in the air are deposited on the surface soil and are recirculated into the air by volatilization or resuspension (RU > Air > SS > Air/SS)¹.
- Pollutants in the air are deposited on the soil and leach into the groundwater (RU > Air > SS > GW)¹.
- Pollutants in the air are deposited on the soil and leach into groundwater, which discharges into surface water (RU > Air > SS > GW > SW)¹.
- Pollutants in the air are deposited on the soil and are washed into surface water via overland runoff (RU > Air > SS > OL > SW)¹.
- The air is the source of known pollutants to be used in the exposure evaluation (Air as a source).

To model releases to the air, MEPAS requires local climatological information, including joint frequency distribution, precipitation, and temperature data. Stack, volatilization, and suspension emission rates can be input or MEPAS can compute emission rates for volatilization and suspension based on site-specific data. Population density and agriculture production for up to a 50-mile radius from the site must be defined two-dimensionally in a matrix of 16 compass directions vs 10 distance intervals.

¹This transport scenario currently involves multiple runs.

3.2 RELEASE FROM SOIL

Contaminant release from soil offers transport scenarios similar to those of the atmospheric release. However, the release originates from an area of contaminated surface soil.

- Pollutants on the soil are recirculated into the air by volatilization or resuspension with some deposition back to the soil (SS > Air/SS).
- Pollutants on the soil leach into the groundwater (SS > GW).
- Pollutants on the soil leach into groundwater, which discharges into surface water (SS > GW > SW).
- Pollutants on the soil wash into surface water via overland runoff (SS > OL > SW).

MEPAS requires site-specific surface soil characterization information. The user must also define (1) the geometry of the contaminated area, (2) the average concentration of the soil contaminant(s), and (3) the soil type.

3.3 RELEASE TO GROUNDWATER

A release to groundwater can be modeled to estimate human exposure in the following ways.

- Pollutants are released into the groundwater and the groundwater is used to affect human exposure via a well or other access method (RU > GW).
- Pollutants are released into groundwater that discharges into surface water (RU > GW > SW).
- Groundwater is the source of known pollutants to be used in the exposure evaluation (GW as a source).

Modeling releases into groundwater requires characterizing the different media (partially saturated and saturated zones) through which the waterborne pollutants pass. The user must identify the sand, silt, and clay content of the zone; pH of the pore water; travel distances in the zone; and thickness, bulk density, total porosity, field capacity, longitudinal dispersion, and saturated hydraulic conductivity of the zone. Absorption coefficients for each contaminant in each zone can be calculated by MEPAS or be supplied by the user.

Transport pathways involving groundwater generally require longer computer processing time than transport through other media. Peak exposures for this transport media also frequently occur beyond the first 70-year time period. Details on the contaminant distribution are provided in the MEPAS output reports.

3.4 RELEASE TO SURFACE WATER

MEPAS models the following transport scenarios for a contaminant release to surface water.

- Pollutants are released into surface water (RU > SW).
- Surface water is the source of known pollutants to be used in the exposure evaluation (SW as a source).
- Pollutants in surface water are volatilizing into the air (SW as a source > Air)².
- Pollutants in surface water are volatilizing into the air and being deposited on the soil (SW as a source > Air > SS)².

Presently, MEPAS considers only nontidal rivers as surface-water bodies for transport. Surface-water flow is assumed to be unidirectional, steady, and uniform. Users must provide the dimensions of the river receiving contamination, the distance to the closest usage location, and the discharge rate (cubic feet per second) of the river at each usage location.

When contaminants enter surface water from an external discharge source (i.e., groundwater or overland runoff), the contaminant concentration in the river for full distribution is calculated as the contaminant flux entering the river divided by the river's discharge rate. MEPAS also calculates concentrations for pollutants that travel an insufficient distance from source to usage location to become fully mixed with river water. MEPAS accounts for dilution through differences in river discharge rates but currently does not account for contaminant adsorption to and desorption from sediment particles.

3.5 DIRECT EXPOSURE

MEPAS models the following direct exposure scenarios:

- Direct soil ingestion
- Measured food concentration ingestion
- Measured radiation dose

To model the direct-exposure pathways, the user must provide the contaminant concentration in soil or food or the measured dose rate of radiation (rads per hour) and an estimate of the number of people exposed. For the measured food concentration ingestion scenario, an average daily intake rate (kilograms per day) for the food product is needed. For direct soil ingestion, the average soil contaminant concentration is used, along with an average life-time ingestion rate of 410 mg/d, to compute risk values.

²This transport scenario currently involves multiple runs.

4. EXPOSURE PATHWAYS

Once the MEPAS user has established the contaminant release media and the transport pathways, the user must define places where humans may be exposed to the destination media. These include groundwater wells, recreation or fishing areas along a river, water intakes for drinking water or irrigation purposes, and inhalation of air and water vapors.

For contamination transported in the atmosphere, MEPAS can simulate exposures to within a 50-mile radius of the site through (1) inhalation of contaminated air and (2) ingestion of agriculture products on which the contaminant has been deposited. The potential routes used for calculating human exposure are listed below.

For exposure to contaminated air/surface soil:

- Air/SS > Inhalation, external exposure, and/or soil ingestion
- Air/SS > Crops > Ingestion
- Air/SS > Crops > Animals > Ingestion

For exposure to contaminated groundwater:

- GW > Ingestion
- GW > Bathing > Ingestion/Inhalation
- GW > Irrigation > Crops > Ingestion
- GW > Irrigation > Crops > Animals > Ingestion
- GW > Animals > Ingestion

For exposure to contaminated surface water (SW):

- SW > Ingestion
- SW > Finfish/Shellfish > Ingestion
- SW > Irrigation > Crops > Ingestion
- SW > Irrigation > Crops > Animals > Ingestion
- SW > Animals > Ingestion
- SW > Bathing > Ingestion
- SW > Recreation > External Exposure
- SW > Recreation > Ingestion

5. HEALTH RISK INDEXES

MEPAS produces two primary health risk indexes: the MII and the *HPI*. These are reported in the MEPAS output file with the *.HPI filename (the Hazard Potential Index Report), where * is the user-defined name of the data set used for the run. An example *HPI* report is given in Appendix B.

The MII is the maximum individual risk value for radionuclides and carcinogenic chemicals and the maximum individual reference dose ratio for noncarcinogenic chemicals. It is determined from the maximum contaminant dose calculated for an individual or group of equally exposed individuals for each of the exposure scenarios given the receptor placement defined to the model. Exposure media for which the MII is evaluated include inhalation of contaminated air; ingestion of drinking water, fish, vegetables, meat, milk and contaminated soil; and exposure to radiation directly and in contaminated surface water through swimming, boating, and shoreline activities.

The MII is calculated independently for each exposure media and route; therefore, the risks or ratios reported are not necessarily common to the same individual but are the highest risks or ratios calculated for contact with a particular contaminant through each independent exposure medium and route. For example, the MII reported for inhalation could be the risk calculated for the person(s) living downwind of and closest to the release site. However, the MII reported for drinking water for the same release unit could be attributed to a different group of people receiving water from an intake nearest a contaminant release to surface water. The MII is calculated according to the risk equations described in Sect. 5.2.

The *HPI* is an indicator of population risk. It is derived from the cumulative risks to the modeled population and is weighted by the number of people exposed. Its calculation is outlined in this section also.

5.1 DOSE CALCULATION

When MEPAS simulates a contaminant's passage through the environmental media selected in the transport scenario, MEPAS calculates a 70-year average environmental concentration at the locations of potential food-chain or human exposure. This concentration, along with other factors, is used in mathematical equations to determine an individual's average dose for the exposure pathways defined for the usage locations.

A dose from radionuclides is expressed as the effective whole-body dose equivalent received over a 70-year lifetime by an average member of the exposed population (rems per 70 years). For chemicals, the dose is the average daily intake (per unit body weight) that an average member of the exposed population would receive (milligrams per kilograms per day). The average person is assumed to weigh 70 kg.

5.2 RISK CALCULATION

Based on the contaminant type (i.e., radionuclide, carcinogenic chemical, or noncarcinogenic chemical), a risk is calculated for each exposure pathway.

5.2.1 Risk for Radioactive Contaminants

The following equation, derived from the BEIR V report (NAS 1990), is used to estimate a radiation health risk:

$$R_{rad} = 6.3E-04 * Dc ,$$

where

R_{rad} = health risk for exposure to radiation from a specific radionuclide (dimensionless),
 $6.3E-04$ = health effect risk factor (per rem),
 Dc = MEPAS-calculated average individual lifetime dose (rem).

5.2.2 Risk for Chemical Contaminants

For chemical contaminants with carcinogenic properties, the equation below is used to evaluate the risk:

$$R_{cc} = Dc * Q ,$$

where

R_{cc} = health risk for exposure to a specific chemical carcinogen (dimensionless),
 Dc = MEPAS-calculated average daily intake rate of a specific chemical carcinogen and exposure pathway (mg/kg/d),
 Q = cancer potency factor for a specific chemical carcinogen [(mg/kg/d)⁻¹].

The reference dose ratio for noncarcinogenic chemicals is evaluated as:

$$R_{nc} = Dc/RfD ,$$

where

R_{nc} = reference dose ratio for exposure to a specific chemical noncarcinogen (dimensionless),
 Dc = MEPAS-calculated average daily intake rate of a specific chemical noncarcinogen and exposure pathway (mg/kg/d),
 RfD = reference dose for a specific chemical noncarcinogen (mg/kg/d).

Cancer potency factors and reference dose values are defined in the MEPAS chemical data base (Streng and Peterson 1989). These values were obtained primarily from EPA's *Integrated Risk Information System* and are updated periodically. Separate values are listed for inhalation and ingestion. To evaluate the risk, MEPAS uses the appropriate value based on the exposure media.

5.3 PRELIMINARY HAZARD POTENTIAL INDEX CALCULATION

Because MEPAS is designed to compare sites that have both carcinogenic and noncarcinogenic chemicals, a relative comparison must be made between cancerous and noncancerous health effects. For a 70-year lifetime exposure to radionuclides or carcinogenic chemicals, a health risk of 10^{-6} (one cancer death predicted for every one million people exposed) or below is considered an acceptable level of risk by EPA. Risks higher than 10^{-4} (i.e., 10^{-2}) are generally considered unacceptable (EPA 1989).

For noncarcinogenic chemicals, the reference dose to which the calculated dose is compared is the estimated acceptable average daily dose for the specific chemical. Doses larger than the reference dose may cause adverse health effects. Therefore, quotients from noncarcinogenic chemical exposures which are greater than one are considered unacceptable.

The threshold of acceptable risk differs between noncarcinogenic chemical exposures (threshold = 1) and radionuclide and carcinogenic chemical exposures (conservative threshold = 10^{-6}). MEPAS multiplies risk values calculated for radioactive contaminants and chemical carcinogens by 10^6 in an attempt to compare cancer risk with noncarcinogenic reference dose ratio values (Whelan et al. 1987). These converted risk values, as well as calculated noncarcinogenic reference dose ratios, are referred to in the following equations as risk factors.

For each exposure pathway, a preliminary hazard potential index (*PI*) is calculated by multiplying the risk factor by the exposed population.

$$PI = RF * P * \exp(-Lt),$$

where

PI = preliminary hazard potential index for a specific contaminant and exposure pathway (persons),

RF = risk factor for the contaminant and exposure pathway (dimensionless),

P = number of people exposed (persons),

L = time constant for the time-weighting function based on a half-time of 70 years (0.01/year) (year^{-1}),

t = time between the beginning of the calculation and the beginning of the current time period (multiples of 70 years).

The *PI* equation includes a time-weighting factor [$\exp(-Lt)$] for exposures extending beyond one 70-year time period for groundwater and surface water scenarios. The atmospheric transport scenarios only deal with the first 70-year period.

The time factor causes the *PI* value for each 70-year period to be approximately half of the *PI* value for the previous 70-year period; thus, exposures that occur in the distant future are discounted and exposures imposing an immediate hazard are given importance.

The model can be directed to calculate the *PI* without applying the time-weighting factor to produce an "undiscounted" *HPI* for each contaminant. MEPAS also applies the time-weighting factor to the *MII* and reports both a discounted and undiscounted *MII*.

5.4 HAZARD POTENTIAL INDEX CALCULATION

For an environmental problem area or release unit, *PI* values for a contaminant are calculated for each exposure pathway, for each 70-year time period, and for each transport pathway modeled. The sum of these *PI* values is used in the following equation to determine the *HPI* for a particular contaminant emitting from the release unit:

$$HPI = 10 (\log_{10} PI),$$

where

HPI = hazard potential index for a particular contaminant from a particular release unit (dimensionless),

PI = the sum of the preliminary hazard potential index values for all exposure pathways modeled for the contaminant within the release unit (persons).

The *HPI* score of the release unit's highest-scoring contaminant is considered the hazard potential index for the unit. The *PI* scores of each modeled contaminant may also be added together within contaminant type (carcinogen or noncarcinogen) and used in the above equation to obtain a multiple contaminant *HPI* for the unit³. Environmental problem areas can then be ranked by either of these common indexes, according to a population-weighted potential health risk.

5.5 HAZARD POTENTIAL INDEX SCORE EVALUATION

HPI values typically range from -250 to 100. The higher the *HPI* score, the more serious the calculated population health risk. Because *HPI* scores are directly related to varying exposure concentrations and populations, guidelines for interpreting *HPI* values are difficult to establish. The following examples from the MEPAS application guidance Volume 1 (Droppo et al. 1989a) provide a concept of *HPI* score representation:

- Exposure of one individual at the reference dose level (noncarcinogen) or cancer potency factor (carcinogen) will give an *HPI* score of 0. This is equivalent to a reference dose ratio of one (noncarcinogen) or an individual lifetime risk of 10^{-6} (carcinogen).
- Exposure of 1 million people at the reference dose level (noncarcinogen) or cancer potency factor (carcinogen) will give an *HPI* score of 60. This is equivalent to a reference dose ratio of one for each of the 1 million people (noncarcinogen) or an individual lifetime risk of 10^{-6} for each of the 1 million people (carcinogen).
- Exposure of 10 million people at 10 times the reference dose level (noncarcinogen) or 10 times the cancer potency factor (carcinogen) will give an *HPI* score of 80. This is equivalent to a reference dose ratio of 10 for each of the 10 million people

³Because of the logarithmic nature of the *HPI*, the multiple contaminant *HPI* will nearly approximate the *HPI* of the highest scoring contaminant.

(noncarcinogen) or an individual lifetime risk of 10^{-5} for each of the 10 million people (carcinogen).

The preceding examples illustrate the general rule that for each order of magnitude increase in population or exposure dose, the *HPI* increases by 10.

The DOE Environment, Safety, and Health Office of Environmental Audit (DOE 1988) categorizes *HPI* scores as follows:

- Scores 71 to 100
Environmental problems of most concern because of the size of usage populations and the toxicity and concentration of the contaminants.
- Scores 51 to 70
Environmental problems of secondary concern. These scores generally represent large usage populations with moderate concentrations and/or toxicity of contaminants. However, a few problems in this group represent small usage populations where toxicity or concentrations are high.
- Scores 31 to 50
Environmental problems of tertiary concern. These scores are generally a result of small usage populations, low doses, or low-toxicity contaminants.
- Scores 1 to 30
Environmental problems generally reaching usage locations at levels well below those used in regulatory decisions.
- Scores 0 or below
Environmental problems not projected to reach usage locations.

Another way to examine the *HPI* is to use the index to calculate the total cancer fatalities predicted to occur as a result of the environmental problem modeled. To do this, the *HPI* is converted back to the *PI*: $PI = 10^{HPI/10}$. The *PI* is then multiplied by 10^{-6} to remove the 10^6 factor used to normalize carcinogenic risks to reference dose ratios (see Sect. 5.3). This leaves the predicted number of cancer fatalities (cancer risk times the exposed population) for each exposure pathway, 70-year time period, and transport pathway included in the *HPI* calculation. The simplified equation is:

$$HE = 10^{(HPI-50)/10}$$

where *HE* = number of cancer fatalities expected over the lifetime of the environmental problem (persons).

This calculation can only be applied to the *HPI* numbers for radionuclides and carcinogenic chemicals. It has little meaning for noncarcinogenic chemicals because the reference dose ratio is not a measure of risk but a comparison between the dose received and the acceptable dose. The population is either getting less than, more than, or the same dose as the reference dose.

6. EXAMPLE APPLICATION OF MEPAS

In this chapter, MEPAS calculations will be applied to the following hypothetical environmental problem to illustrate the methodology MEPAS uses in assigning an *HPI*. The *.*HPI* and *.*WAT* MEPAS output files for this example are presented in Appendix B and Appendix C, respectively.

An industry is releasing ^{137}Cs (at 0.57 Ci/year), polychlorinated biphenyls (PCBs) (at 4200 g/year), and mercury (at 672 g/year) into a stream that flows into a river. These releases are expected to continue at the same rate for 40 years. An intake that draws, treats, and distributes river water for domestic use is located along the river. The river is also used for recreation: shoreline activities, swimming, and boating. The population eats finfish from the river. It is assumed that the river contains approximately the same volume of water at each of the usage locations.

6.1 DOSE CALCULATION

Using input data describing the release, transport pathway, and environmental media, MEPAS simulates contaminant transport to the usage locations modeled. The 70-year average concentration in the surface water is then calculated for each contaminant at these usage locations. The 70-year average contaminant concentrations in water are found in the MEPAS output file with a *.*WAT* filename, where * is the user-defined name of the data set used for the run. The concentrations are in the next-to-last column and are in units of atto (10^{-18}) curies per milliliter or atto grams per milliliter. These units must be converted to pico curies per liter or milligrams per liter for use in the following dose calculations. A set of concentrations is given for each usage location.

The concentration values in the *.*WAT* file do not account for decay or degradation of contaminants which occurs in transit from the source to the usage location. MEPAS version 2.1G includes the following equation to more accurately estimate contaminant concentrations at the usage location:

$$C_w = C_a * \exp(-\lambda_w * t)$$

where

C_w = average water concentration of the contaminant after decay or degradation (mg/L or pCi/L)

C_a = average water concentration of the contaminant obtained from the *.*WAT* file (mg/L or pCi/L)

λ_w = environmental degradation or radiological decay constant for the contaminant in surface water (d^{-1})

t = contaminant travel time from source to usage location (d)

The decay constant for the contaminant in surface water (λ_w) is computed as:

$$\lambda_w = (\ln 2)/t,$$

where t = the contaminant environmental half-life in surface water listed in the MEPAS chemical data base in days. The contaminant travel time is computed as the distance to the first usage location divided by the velocity of the surface water. In this example, the first usage location is 8000 ft from the source and the velocity of the river is 0.8 ft/sec. The contaminant travel time is 10,000 seconds or 0.116 days.

6.1.1 Drinking Water

MEPAS uses the following equation to calculate the dose an average individual would receive by ingesting drinking water from a contaminated source:

$$D_w = U_w * C_w * T_f * D_g * \exp(-\lambda_w * t_p),$$

where

D_w = average individual dose for a specific contaminant from ingesting drinking water (mg/kg/d or rem/70 years),

U_w = average daily water intake rate for an individual (L/d),

C_w = average water concentration of the contaminant (mg/L or pCi/L),

T_f = water purification factor, fraction of contaminant remaining after treatment (dimensionless).

D_g = ingestion dose conversion factor for the contaminant (kg⁻¹ or rem/pCi),

λ_w = environmental degradation or radiological decay constant for the contaminant in surface water (d⁻¹),

t_p = average time of transit through the water distribution system (day).

As the average rate of daily water intake (U_w), MEPAS uses 2 L/d for drinking water plus 0.01 L/d ingested from domestic bathing. For radionuclides such as ¹³⁷Cs, the amount of water ingested over a 70-year period (5.14E+04 liters) must be used. The contaminant concentration in the water at the intake (C_w) can be obtained from the *.WAT output file and refined as described above.

The MEPAS chemical data base contains the water treatment purification factor (T_f) for each contaminant. It is the estimated percentage of the contaminant that remains following common water treatment processing. If the water is not treated before drinking, all contaminants will have a purification factor of one.

The ingestion dose conversion factor (D_g) for chemical contaminants is 1/70 kg to relate dose to unit body weight of an average adult. For radionuclides, D_g is the ingestion dose factor in the MEPAS chemical data base. The decay constant for the contaminant in surface water (λ_w) is computed as shown above. The MEPAS default value of 0.5 d for the average time of transit through the water distribution system (t_p) will be used in this example.

Table 1 shows the values of variables and the average individual dose from drinking water ingestion for each of the contaminants considered in this example.

Table 1. Drinking water dose calculation values

Contaminant	C_w	T_f	D_g	λ_w (d ⁻¹)	Dose (D_w)
Cesium-137	7.40E-02 pCi/L	0.9	5.0E-08 rem/pCi	6.3E-05	1.71E-04 rem/ 70 year
PCBs	4.10E-07 mg/L	0.1	1.43E-02 kg ⁻¹	2.47E0	3.42E-10 mg/kg/d
Mercury	8.73E-08 mg/L	0.5	1.43E-02 kg ⁻¹	1.0E-08	1.25E-09 mg/kg/d

6.1.2 Recreation

Exposure from surface-water contaminants in recreational areas is attributed primarily to radionuclides. The following equation combines calculated radionuclide exposures during boating, swimming, and shoreline activities.

$$De = 70 * (0.5 * tb + ts) * Cw * Db + 70 * tf * Cd * W * Ds ,$$

where

De = radiation dose to an individual from external exposure to a specific radionuclide (rem/70 year),

tb = average time spent by an individual boating (h/year),

ts = average time spent by an individual swimming (h/year),

Cw = average water concentration of the contaminant (pCi/L),

Db = external dose conversion factor for the radionuclide for immersion in water (rem*L/pCi*h),

tf = average time spent by an individual in shoreline activities (h/year),

Cd = average sediment concentration of the contaminant deposited on the shoreline from contaminated water (pCi/m²),

W = shore-width factor to correct for finite size of shoreline (dimensionless),

Ds = external dose conversion factor for exposure to a contaminated plane (soil exposure factor) of the radionuclide (rem*m²/pCi*h).

The average individual is estimated to spend 12 h/year in each of the three activities considered (tb , ts , and tf). The boating exposure time is reduced by half ($0.5 * tb$), because only partial immersion in water is experienced. The MEPAS chemical data base contains dose conversion factors for immersion in water (Db) and exposure to contaminated soil (Ds). MEPAS uses 0.2 as the shore-width factor (W) derived from experimental data (Dunster 1971). The average contaminant concentration in shoreline sediments (Cd) is estimated using the following equation (Soldat et al. 1974):

$$Cd = 100 * t * Cw * [1 - \exp(-\lambda_s * tw)] ,$$

where

- C_d = average sediment concentration of the contaminant deposited on the shoreline from contaminated water (pCi/m²),
 100 = transfer constant from water to sediment (L/m²/d),
 t = physical half-life of the radionuclide (d),
 C_w = average water concentration of the contaminant (pCi/L),
 λ_s = radiological decay constant for the contaminant in soil (d⁻¹),
 t_w = length of time the shoreline sediment is exposed to the contaminated water.

The MEPAS chemical data base contains the physical half-life of the radionuclide (t). The radiological decay constant (λ_s) is calculated as discussed for the drinking water dose, using the value for the half-life in soil instead of surface water. The length of time the shoreline sediment is exposed to the contaminated water (t_w) is estimated at half the 70-year evaluation period or 12,780 days.

Table 2 shows the values of variables and the calculated average individual exposure dose from swimming, boating, and shoreline activities in and around contaminated surface-water recreational areas.

Table 2. Recreation dose calculation values

Contaminant	C_w	D_b	C_d	D_s	Dose (D_e)
Cesium-137	7.40E-02 pCi/L	6.9E-10 rem*L/pCi*h	4.50E+04 pCi/m ²	6.8E-12 rem*m ² /pCi*h	5.15E-05 rem/70 year

MEPAS also calculates the dose an individual would receive by inadvertently ingesting water while swimming. Unlike the previously calculated doses for the recreation pathway, this dose is calculated for nonradionuclides as well as radionuclides. The following equation is used:

$$D_r = 0.10 * C_w * t_s * D_g / 365 ,$$

where

- D_r = average dose of a particular contaminant an individual receives by inadvertently ingesting water while swimming (mg/kg/d or rem/70 years),
 0.10 = inadvertent water ingestion rate during recreational swimming (L/h),
 C_w = average water concentration of the contaminant (mg/L or pCi/L),
 t_s = average time an individual spends swimming (12 h/year),
 D_g = ingestion dose conversion factor for the contaminant (kg⁻¹ or rem/pCi),
 365 = days per year.

Table 3 shows the calculated values of variables and doses applicable to ingestion of contaminated water while swimming.

Table 3. Swimming dose calculation values

Contaminant	C_w	D_g	Dose (D_r)
Cesium-137	7.40E-02 pCi/L	5.0E-08 rem/pCi	3.12E-07 rem/70 year
PCBs	4.10E-07 mg/L	1.43E-02 kg ⁻¹	1.93E-11 mg/kg/d
Mercury	8.73E-08 mg/L	1.43E-02 kg ⁻¹	4.10E-12 mg/kg/d

6.1.3 Fishing

River contaminants enter the food chain and affect the population when people eat finfish caught from the river. MEPAS uses the following equation to calculate the average individual dose from ingestion of finfish:

$$D_f = U_f * C_w * B_f * D_g * \exp(-\lambda_w * t_f),$$

where

D_f = average individual dose from ingesting finfish for a particular contaminant (mg/kg/d or rem/70 year),

U_f = average individual consumption rate of finfish (kg/d),

C_w = average water concentration of the contaminant (mg/L or pCi/L),

B_f = bioaccumulation factor for finfish and the specific contaminant (L/kg),

D_g = ingestion dose conversion factor for the contaminant (kg⁻¹ or rem/pCi),

λ_w = environmental degradation or radiological decay constant for the contaminant in surface water (d⁻¹),

t_f = average time for decay from food harvest to consumption (d).

The average individual consumption rate for finfish is estimated as 0.0065 kg/d. To calculate radionuclide exposure, the amount of finfish the average individual ingests over a 70-year period (1.66E+02 kg) must be used. For each constituent, the MEPAS chemical data base defines the bioaccumulation factors used for finfish and other food sources. The MEPAS default values for the average decay time from food harvest to consumption (t_f), 0.5 d, will be used in this example.

Table 4 gives the values of variables and the average dose an individual receives from ingesting finfish for each of the contaminants considered in this example.

Table 4. Finfish ingestion dose calculation values

Contaminant	C_w	B_f (L/kg)	Dose (D_f)
Cesium-137	7.40E-02 pCi/L	2.0E+03	1.23E-03 rem/70 year
PCBs	4.10E-07 mg/L	1.8E+05	1.99E-06 mg/kg/d
Mercury	8.73E-08 mg/L	2.0E+05	1.62E-06 mg/kg/d

6.2 RISK CALCULATION

Using the doses for each potential exposure, the risk and reference dose ratio can be calculated by the formulas discussed in Sect. 4. Because this example has only one usage location for each exposure to drinking water, recreational activities, and finfish and each location considers a population of equally exposed individuals, these risk and reference dose ratio values are also reported by MEPAS as the MIIs for each contaminant and exposure. Tables 5, 6, and 7 show the risk for each contaminant and exposure in this example calculation.

Table 5. Risk for ^{137}Cs (radionuclide)

Exposure	Dose (rem/70 year)	Risk
Drinking water	1.71E-04	1.08E-07
Recreation	5.15E-05	3.24E-08
Swimming	3.12E-07	1.96E-10
Finfish	1.23E-03	7.74E-07

Table 6. Risk for polychlorinated biphenyls (chemical carcinogen)

Exposure	Dose (mg/kg/d)	Cancer potency factor [(mg/kg/d) ⁻¹]	Risk
Drinking water	3.42E-10	7.7	2.64E-09
Swimming	1.93E-11	7.7	1.48E-10
Finfish	1.99E-06	7.7	1.54E-05

Table 7. Risk for mercury (chemical noncarcinogen)

Exposure	Dose (mg/kg/d)	Reference dose (mg/kg/d)	Reference dose ratio
Drinking water	1.25E-09	3.0E-04	4.18E-06
Swimming	4.10E-12	3.0E-04	1.37E-08
Finfish	1.62E-06	3.0E-04	5.41E-03

6.3 PRELIMINARY HAZARD POTENTIAL INDEX CALCULATION

After multiplying the risk values calculated for the radionuclide and carcinogenic chemicals (^{137}Cs and PCBs) by 10^5 (see Sect. 5.3), the risk factors can be multiplied by the population present at each exposure and then totaled for each contaminant to determine the *PI*. The population using water from the intake is estimated to be 2000 people. One hundred eighty thousand people are estimated to use the recreational area of the river. An estimated 10,000 kg of finfish are consumed from the river each year. The number of people affected by this food source is computed as follows:

$$Pf = Pd / (Ir * 365),$$

where

- Pf* = population affected by the food source,
- Pd* = production rate of food source (kg/year or L/year),
- Ir* = average individual ingestion rate of food source (kg/d or L/d),
- 365 = days per year.

MEPAS estimates that the average individual ingests 0.0065 kg/d of finfish each year. An estimated 4215 people are calculated as being exposed to contaminated finfish from the river. Tables 8, 9, and 10 show *PI* calculations for each contaminant.

Table 8. *PI* values for ^{137}Cs

Exposure	Risk factor	Population	<i>PI</i>
Drinking water	1.08E-01	2000	2.16E+02
Recreation	3.24E-02	180,000	5.83E+03
Swimming	1.96E-04	180,000	3.53E+01
Finfish	7.74E-01	4215	3.26E+03
Total <i>PI</i>			9.34E+03

Table 9. *PI* values for polychlorinated biphenyls

Exposure	Risk factor	Population	<i>PI</i>
Drinking water	2.64E-03	2000	5.28E0
Swimming	1.48E-04	180,000	2.66E+01
Finfish	1.54E+01	4215	6.49E+04
Total <i>PI</i>			6.49E+04

Table 10. *PI* values for mercury

Exposure	Risk factor	Population	<i>PI</i>
Drinking water	4.18E-06	2000	8.36E-03
Swimming	1.37E-08	180,000	2.47E-03
Finfish	5.41E-03	4215	2.28E+01
Total <i>PI</i>			2.28E+01

6.4 HAZARD POTENTIAL INDEX CALCULATION

The *HPI* is calculated as described in Sect. 5.4 using the total *PI* value. Table 11 shows the *HPI* scores for each contaminant modeled in this example.

Table 11. *HPI* scores for example problem

Contaminant	<i>PI</i>	<i>HPI</i>
Cesium-137	9.34E+03	39.7
PCBs	6.49E+04	48.1
Mercury	2.28E+01	13.6

The highest *HPI* score is the PCB score of 48.1, resulting primarily from ingestion of finfish. This score is considered to be the *HPI* of the example environmental problem for the surface-water transport pathway.

7. CONCLUSION

MEPAS is a complex pollutant simulation model that requires experience in personal computer operations and an extensive knowledge of the conditions surrounding the environmental problems modeled. Although this report does not attempt to analyze the MEPAS code in detail, the calculations and methods used to simulate contaminant transport and evaluate contaminated sites are adequate.

Contaminant releases can be modeled to the atmosphere, surface soil, groundwater, and surface water. MEPAS can simulate contaminant transport through multiple environmental media to potential human exposure locations. Direct ingestion of contaminated soil, ingestion of a measured contaminant concentration in food, and measured direct radiation can also be simulated.

MEPAS evaluates the health risk of the average person using average inhalation and consumption rates for a 70-year lifetime. The MII, showing individual risk, and the *HPI*, measuring population risk, are produced as indicators of potential human health risk.

REFERENCES

- Buck, J. W. et al. December 1989. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance—Getting Started with MEPAS*, PNL-7136, Pacific Northwest Laboratory, Richland, Washington.
- DOE. September 1988. *Environmental Survey Preliminary Summary Report of the Defense Production Facilities*, DOE/EH-0072, Washington, D.C.
- Droppo, J. G., Jr. et al. December 1989a. *Multimedia Environmental Pollutant Assessment System (MEPAS®) Application Guidance. Volume 1—User's Guide*, PNL-7216-Vol. 1, Pacific Northwest Laboratory, Richland, Washington.
- Droppo, J. G., Jr. et al. December 1989b. *Multimedia Environmental Pollutant Assessment System (MEPAS®) Application Guidance. Volume 2—Guidelines for Evaluating MEPAS Input Parameters*, PNL-7216-Vol. 2, Pacific Northwest Laboratory, Richland, Washington.
- Dunster, H. J. (chairman). 1971. *Handbook of Radiological Protection Part 1: Data*, SNB 11=360079-8, Radioactivity Advisory Committee, Department of Employment, Department of Health and Social Security, Ministry of Health and Social Services, Northern Ireland; Her Majesty's Stationery Office, London.
- EPA. 1982. *Health Effects Assessment Summary for 300 Hazardous Organic Constituents*, Environmental Criteria and Assessment Office, U.S. Environmental Protection Agency, Cincinnati, Ohio.
- EPA. 1989. *Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual Part A*, U. S. Environmental Protection Agency, Cincinnati, Ohio.
- NAS (National Academy of Sciences). 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V*. National Academy of Sciences Committee on the Effects of Ionizing Radiations, National Research Council, Washington, D.C.
- Soldat, J. K., N. M. Robinson, and D. A. Baker. 1974. *Models and Computer Codes for Evaluating Environmental Radiation Doses*, BNWL-1754, Pacific Northwest Laboratory, Richland, Washington.
- Streng, D. L. and S. R. Peterson. September 1989. *Chemical Data Bases for the Multimedia Environmental Pollutant Assessment System (MEPAS): Version 1*, Pacific Northwest Laboratory, Richland, Washington.
- Whelan, G. et al. December 1989. *A Demonstration of the Applicability of Implementing the Enhanced Remedial Action Priority System (RAPS) for Environmental Releases*, Pacific Northwest Laboratory, Richland, Washington.
- Whelan, G. et al. August 1987. *The Remedial Action Priority System (RAPS): Mathematical Formulations*, DOE/RL-87-09, PNL-6200, Pacific Northwest Laboratory, Richland, Washington.

Appendix A
INPUT AND OUTPUT FILES CREATED BY MEPAS

Input and Output Files Created by MEPAS

Input Files Created by MEPAS

File name	Component	File contents
*.BAT	Generic	Batch command file
*.DET	Atmospheric	Contaminant data file used by the volatilization component
*.HIN	Exposure	Usage location input
*.ID	Generic	Control file containing the names of files to be run
*.JFD	Atmospheric	Joint frequency distribution used in worksheet 3.2
*.MET	Atmospheric	Meteorology input
*.POP	Atmospheric	Population distribution used in worksheet 4.3
*.SOU	Atmospheric	Source-term input
*.TOP	Atmospheric	Topography and surface roughness
*.WIN	Waterborne	Source-term and environmental input

* Represents the user-defined name of the data set used for the run.

Input and Output Files Created by MEPAS

Output Files Created by MEPAS

File name	Component	File contents
*.AIR	Atmospheric	70-year average air concentration used as input to the exposure component
*.ALC	Atmospheric	Intermediate mass budget data
*.ALS	Atmospheric	Intermediate meteorological, emission, and dispersion data
*.CNC	Atmospheric	Contaminant concentrations used by the exposure component
*.HPI	Exposure	Final report showing computed HPI and MII values
*.POL	Waterborne	Intermediate results of detailed pollutograph (concentration versus time)
.RSK	Exposure	Intermediate HPI results used to produce the HPI summary report (.THP)
*.THP	Exposure	Final summary report combining HPIs for different runs within the same hierarchical unit
*.VOL	Atmospheric	Volatilization emission rates (g/s) used by the exposure component
*.WAT	Waterborne	70-year average water concentrations used as input to the exposure component
*.WLS	Waterborne	Intermediate processed input and calculated data, peak concentrations and time of arrival for each contaminant

* Represents the user-defined name of the data set used for the run.

Appendix B

EXAMPLE *HPI* OUTPUT FILE

Example HPI Output File

Multimedia Environmental Pollutant Assessment System (MEPAS)

MEPAS Hazard Potential Output (VERSION 041292)

Pacific Northwest Laboratory

Richland, WA 99352

Developed for the U.S. Department of Energy

Run Date and Time: 4/14/1992 16: 2:32

(This run used 630. effects per million man-rem)

Run Title: Example Ranking Unit

Ranking Unit 1 : EXAMPLE

Number of Constituents is: 3

Time Discounted HPIs are computed using 70 year time periods (Time Index = 0)

Num	Constituent Names -----	CASID -----
1	CESIUM-137+D	CS137
2	Mercury, Quicksilver	7439976
3	Aroclor, PCB (General Classification), Thermal	1336363

Example HPI Output File

Summary of Data from MEPAS Constituent Database
 COMBINED DATA LIBRARY FOR RAPS/MEPAS - UPDATED AUGUST 16, 1991

This Database Contains Entries for 397 Constituents

Constituent Parameter	Parameter Units	Constituent 1	Constituent 2	Constituent 3
ID / CAS #:	(None)	CS137	7439976	1336363
Toxicity Type:	(None)	1	5	2
Mol. Weight:	g/mole	1.370E+02	2.010E+02	3.280E+02
Vapor Pressure:	mm-Hg	0.000E+00	2.000E-03	7.700E-05
Henry's Law Con:	atm*m3/mole	0.000E+00	1.140E-03	2.600E-03
Water Sol:	mg/L	0.000E+00	3.000E-02	3.100E-02
Carbon Mat Part:	ml/g	0.000E+00	0.000E+00	6.100E+05
Oct Wat Part:	(None)	0.000E+00	0.000E+00	1.100E+06
1/2-life in AIR:	days	1.100E+04	6.900E+07	6.900E+07
1/2-life in GW:	days	1.100E+04	6.900E+07	6.900E+07
1/2-life in SW:	days	1.100E+04	6.900E+07	2.810E-01
1/2-life in SOIL:	days	1.100E+04	6.900E+07	1.250E+07
Ing Dose Fact:	1/Kg or rem/pCi	5.000E-08	1.430E-02	1.430E-02
Inh Dose Fact:	1/Kg or rem/pCi	3.200E-08	1.430E-02	1.430E-02
Air Imm Fact:	rem*m3/pCi*h	3.400E-10	0.000E+00	0.000E+00
Soil Exp Fact:	rem*m2/pCi*h	6.800E-12	0.000E+00	0.000E+00
Water Imm Fact:	rem*L/pCi*h	6.900E-10	0.000E+00	0.000E+00
Fish Bioaccum:	(None)	2.000E+03	2.000E+05	1.800E+05
Shell Bioaccum:	(None)	1.000E+02	2.000E+05	6.337E+03
Veg Bioaccum:	(None)	2.000E-03	3.800E-01	3.119E-03
Meat Trans Fact:	day/Kg	3.000E-02	1.000E-01	2.763E-02
Milk Trans Fact:	day/L	5.000E-03	1.900E-02	8.738E-03
Water Pur Fact:	(None)	9.000E-01	5.000E-01	1.000E-01
Dep Velocity:	m/sec	1.000E-03	1.000E-03	7.410E-04
Atmos Dis Class:	(None)	1	1	6
Inh Cancer Pot:	(Kg*day)/mg	0.000E+00	0.000E+00	7.700E+00
Ing Cancer Pot:	(Kg*day)/mg	0.000E+00	0.000E+00	7.700E+00
Inh Ref Dose:	mg/(Kg*day)	0.000E+00	3.000E-04	0.000E+00
Ing Ref Dose:	mg/(Kg*day)	0.000E+00	3.000E-04	0.000E+00
Inh Tox Uncert	HPI units	5	5	10
Ing Tox Uncert	HPI units	5	5	5
Phys Prop Uncert	HPI units	3	3	8
Tran Fact Uncert	HPI units	3	3	10

 Toxicity Type 1: Radionuclide carcinogenic inhalation and ingestion
 Toxicity Type 2: Chemical carcinogenic inhalation and ingestion
 Toxicity Type 3: Chemical carcinogenic inhalation, non-carcinogenic ingestion
 Toxicity Type 4: Chemical non-carcinogenic inhalation, carcinogenic ingestion
 Toxicity Type 5: Chemical non-carcinogenic inhalation and ingestion

KEY for Constituent Table

Constituent 1 = CESIUM-137+D
 Constituent 2 = MERCURY
 Constituent 3 = PCBs (GENERAL)

Example HPI Output File

USAGE LOCATION DATA FOR SURFACE WATER PATHWAY

Location Parameter	Units	Location 1	Location 2	Location 3
Drink Index:	(None)	2	0	0
Drink Pop:	People	2.000E+03	0.000E+00	0.000E+00
Rec Index:	(None)	0	0	4
Rec Pop:	People	0.000E+00	0.000E+00	1.800E+05
Aquatic Index:	(None)	0	1	0
FinFish Prod:	Kg/yr	0.000E+00	1.000E+04	0.000E+00
Shell Prod:	Kg/yr	0.000E+00	0.000E+00	0.000E+00
Irr Index:	(None)	0	0	0
Leaf Veg Prod:	Kg/yr	0.000E+00	0.000E+00	0.000E+00
Veg Product:	Kg/yr	0.000E+00	0.000E+00	0.000E+00
Meat Product:	Kg/yr	0.000E+00	0.000E+00	0.000E+00
Milk Product:	L/yr	0.000E+00	0.000E+00	0.000E+00
SW Trans Time:	days	6.940E+00	6.940E+00	6.940E+00
Irr. Rate:	L/mo	1.000E+02	1.000E+02	1.000E+02
Harvest Time:	days	6.000E+01	6.000E+01	3.000E+01
Transit Time:	days	5.000E-01	0.000E+00	0.000E+00
Water Treated:	yes/no	Yes	No	No
H2O Ing Rate:	L/day	2.000E+00	2.000E+00	2.000E+00
Fish Time Delay:	days	1.000E+01	1.000E+01	1.000E+01
Inv time delay:	days	1.000E+01	1.000E+01	1.000E+01

=====
Drinking Index ----> 0 = No Drinking or Bathing, 1 = Bathing Only, and
2 = Drinking and Bathing
Recreation Index --> 1 = Swimming Only, 2 = Boating Only,
3 = Shoreline Activities Only, and 4 = All of the Above
Aquatic Index -----> 0 = No Aquatic food, 1 = Aquatic Food
Irrigation Index --> -1 = Animals Drinking Only, 0 = No Farm Production,
1 = Crops and Animals [Feed and Water], and
2 = Crops and Animals Feed Only
=====

KEY for Usage Location in Table

Usage Location 1 = Drinking Water Intake
Usage Location 2 = Fishing Area
Usage Location 3 = Recreation Area

Example HPI Output File

HPI Values by Usage Location for the SURFACE WATER Transport Pathway

Usage Location	Constituent		
	1	2	3
Drinking Water Intake	23.34	-20.78	7.22
Fishing Area	35.13	13.57	48.12
Recreation Area	37.71	-26.07	14.26
Total for Constituent	39.72	13.58	48.12

--- Constituent Names ---

Constituent 1 = CESIUM-137+D

2 = MERCURY

3 = PCBs (GENERAL)

Example HPI Output File

Maximum Individual Risk Values/RfD Ratios

Exposure Route	[CESIUM-137+D]				[MERCURY]			
	Time Weighted		Non-Time Weighted		Time Weighted		Non-Time Weighted	
	Risk Value	Time Per.	Risk Value	Time Per.	RfD Ratio	Time Per.	RfD Ratio	Time Per.
INGESTION/DERMAL								
Drinking Water	1.08E-07	1	1.08E-07	1	4.18E-06	1	4.18E-06	1
Finfish	7.74E-07	1	7.74E-07	1	5.41E-03	1	5.41E-03	1
Shellfish	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Leafy Vegetables	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Other Vegetables	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Meat	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Milk	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Swimming	2.24E-10	1	2.24E-10	1	1.37E-08	1	1.37E-08	1
Soil Ingestion	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Special Foods	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
INHALATION								
Inhalation	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
Showering	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0
EXTERNAL RADIATION								
Boating	1.36E-11	1	1.36E-11	1	0.00E+00	0	0.00E+00	0
Shoreline	3.25E-08	1	3.25E-08	1	0.00E+00	0	0.00E+00	0
Ground	0.00E+00	0	0.00E+00	0	0.00E+00	0	0.00E+00	0

 For radionuclides and carcinogenic chemicals, RISK VALUES are used
 For non-carcinogenic chemicals, RfD VALUES are used [dose/RfD]

Example HPI Output File

Maximum Individual Risk Values/RfD Ratios (Cont)

Exposure Route	[PCBs (GENERAL)]			
	Time Weighted		Non-Time Weighted	
	Risk Value	Time Per.	Risk Value	Time Per.
INGESTION/DERMAL				
Drinking Water	2.64E-09	1	2.64E-09	1
Finfish	1.54E-05	1	1.54E-05	1
Shellfish	0.00E+00	0	0.00E+00	0
Leafy Vegetables	0.00E+00	0	0.00E+00	0
Other Vegetables	0.00E+00	0	0.00E+00	0
Meat	0.00E+00	0	0.00E+00	0
Milk	0.00E+00	0	0.00E+00	0
Swimming	1.48E-10	1	1.48E-10	1
Soil Ingestion	0.00E+00	0	0.00E+00	0
Special Foods	0.00E+00	0	0.00E+00	0
INHALATION				
Inhalation	0.00E+00	0	0.00E+00	0
Showering	0.00E+00	0	0.00E+00	0
EXTERNAL RADIATION				
Boating	0.00E+00	0	0.00E+00	0
Shoreline	0.00E+00	0	0.00E+00	0
Ground	0.00E+00	0	0.00E+00	0

 For radionuclides and carcinogenic chemicals, RISK VALUES are used
 For non-carcinogenic chemicals, RfD VALUES are used [dose/RfD]

Example HPI Output File

File Title Summary For Run

Run Title: Example Ranking Unit --- EXAMPLE .HIN

Run Date and Time: 4/14/1992 16: 2:52

Constituent Database:UPDATED AUGUST 16, 1991

Water Data File: Examl --- EXAMPLE .WAT

Appendix C

EXAMPLE WAT OUTPUT FILE

Example WAT Output File

Example	Facility		Example Ranking Unit			
1	1	3				
3						
1	1	CESIUM-1	CS137	3.500E+01	7.401E+01	1.000E-18
-88						
1	2	MERCURY	7439976	3.500E+01	8.725E+04	1.000E-18
-88						
1	3	PCBS (GE	1336363	3.500E+01	5.453E+05	1.000E-18
-88						
1	2	3				
3						
1	1	CESIUM-1	CS137	3.500E+01	7.401E+01	1.000E-18
-88						
1	2	MERCURY	7439976	3.500E+01	8.725E+04	1.000E-18
-88						
1	3	PCBS (GE	1336363	3.500E+01	5.453E+05	1.000E-18
-88						
1	3	3				
3						
1	1	CESIUM-1	CS137	3.500E+01	7.401E+01	1.000E-18
-88						
1	2	MERCURY	7439976	3.500E+01	8.725E+04	1.000E-18
-88						
1	3	PCBS (GE	1336363	3.500E+01	5.453E+05	1.000E-18
-88						
-99						

DISTRIBUTION

- | | |
|----------------------|---------------------------------------|
| 1. L. D. Bates | 16. P. T. Owen |
| 2. W. R. Brown | 17. G. E. Rymer |
| 3. K. W. Cook | 18. R. H. Snyder |
| 4. D. G. Cope | 19. D. W. Swindle |
| 5. M. F. P. DeLozier | 20. C. C. Travis |
| 6. T. K. Evers | 21. R. K. White |
| 7. C. D. Goins | 22. G. E. Whitesides |
| 8. J. L. Haymore | 23. Central Research Library |
| 9. S. V. Kaye | 24-26. Environmental Sciences Library |
| 10. B. L. Kimmel | 27-31. ER Document Management Center |
| 11-15. K. L. Michel | 32. ORNL Laboratory Records |
33. P. H. Edmonds, Radian Corporation, 120 South Jefferson Circle, Oak Ridge, TN 37830
- 34-37. W. E. Murphie, DOE, Office of Environmental Restoration, Eastern Area D&D Branch, EM-423 (GTN), Washington, DC 20545
- 38-39. R. C. Sleeman, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
40. S. P. Riddle, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
41. C. S. Gist, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
42. W. N. Lingle, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
43. S. L. Lankford, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
44. A. T. Manion, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
45. D. G. Page, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
46. M. A. Travaglini, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
47. A. B. Perkins, DOE Oak Ridge Field Office, P.O. Box 2001, Oak Ridge, TN 37831-8541
48. D. W. Dollins, DOE Oak Ridge Field Office, Bldg. XT-801, Piketon, OH 45661
49. R. C. Edwards, DOE Oak Ridge Field Office, Bldg. C-100, Paducah, KY 42001
50. T. Longo, DOE, 12800 Middlebrook Road, Trevion 2 Building, Germantown, MD 20874
51. F. Baxter, DOE, 12800 Middlebrook Road, Trevion 2 Building, Germantown, MD 20874
52. G. P. Turi, DOE, 12800 Middlebrook Road, Trevion Building, Germantown, MD 20874
53. R. J. Aiken, DOE, 1000 Independence Avenue, Suite GE045, Washington, DC 20585
54. Jack Craig, DOE Fernald Field Office, P.O. Box 398705, Cincinnati, Ohio 45239-8705
55. W. W. Tolbert, Science Applications International Corporation, 301 laboratory Road, Oak Ridge, TN 37830
56. Ken Duke, Science Applications International Corporation, 301 laboratory Road, Oak Ridge, TN 37830
57. Sue Peterman, Westinghouse Materials Company of Ohio, 7400 Willey Road, Fernald, Ohio 45030
- 58-59. J. Droppo, Battelle Pacific Northwest Laboratories, Batelle Boulevard, P.O. Box 999, K6-76, Richland, WA 99352
60. A. Toblin, Halliburton NUS Environmental Corporation, 910 Clipper Road, Gaithersburg, MD 20877

OFFICE OF ASSISTANT MANAGER, ENERGY RESEARCH AND DEVELOPMENT,
 U.S. DEPARTMENT OF ENERGY, DOE FIELD OFFICE, OAK RIDGE,
 POST OFFICE BOX 2001, OAK RIDGE, TN 37831-8600

OFFICE OF SCIENTIFIC AND TECHNICAL INFORMATION, P.O. BOX 62,
 OAK RIDGE, TN 37831

END

**DATE
FILMED**

8 / 26 / 92

