13.0 Human Exposure Module

13.1 Purpose and Scope

The Human Exposure Module calculates the applied dose to human receptors from ingestion and inhalation of contaminated media and food. Detailed information on the Human Exposure Module can be found in the background document (U.S. EPA, 2000). Figure 13-1 shows the relationship and information flow between the Human Exposure Module and the

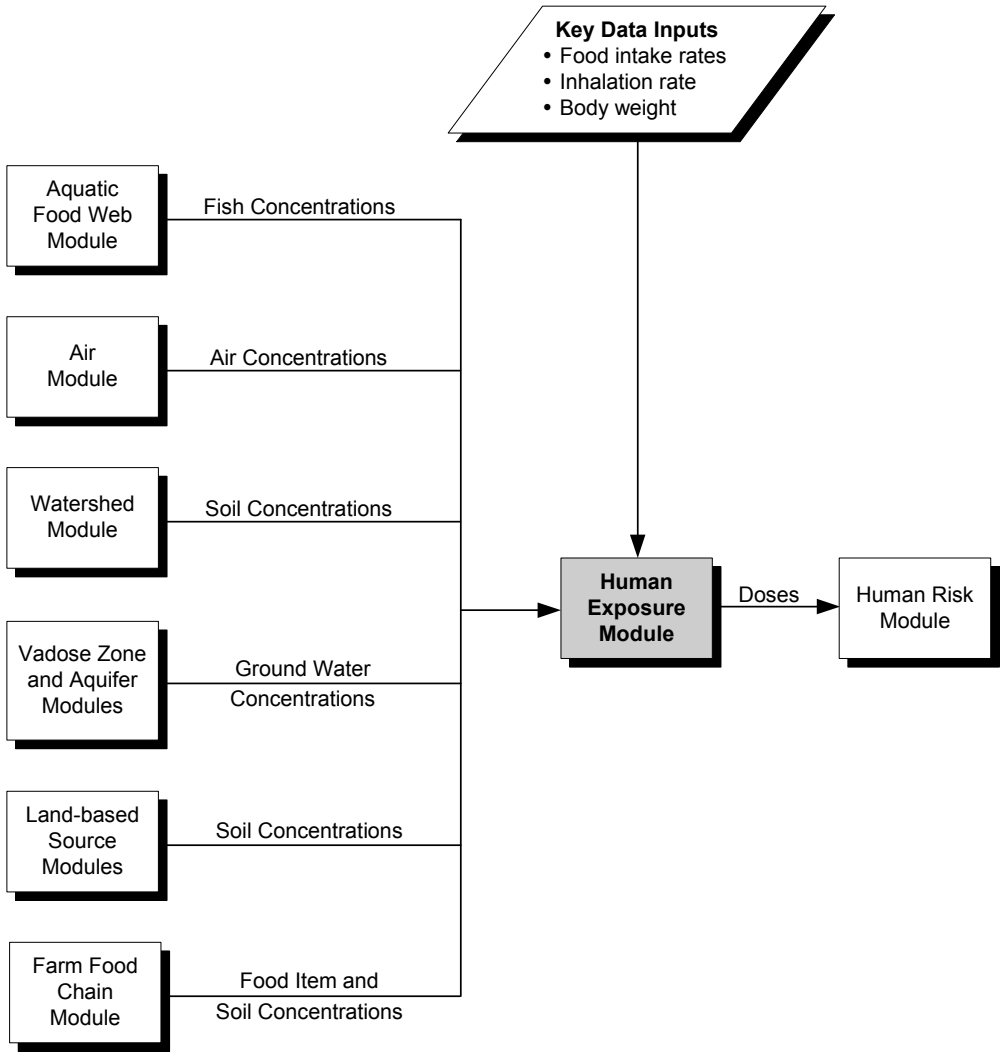

Figure 13-1. Information flow for the Human Exposure Module in the 3MRA modeling system.

3MRA modeling system. The Human Exposure Module uses media and food concentrations calculated in the media and food web modules to calculate applied doses. These doses are used by the Human Risk Module to calculate risk measures.

The purpose of the Human Exposure Module is to calculate the exposure inputs needed by the Human Risk Module to calculate receptor risk and hazard. For carcinogens, risk is calculated from applied dose (in mg/kg-d). For noncarcinogens, hazard via the ingestion pathway is also based on dose, whereas hazard via the inhalation pathway is based on the air concentration to which a receptor is exposed. Thus, the Human Exposure Module has the following functions:

1. **Calculates ambient air concentrations**. The Human Exposure Module calculates areal average ambient air concentrations for farms. Ambient (outdoor) air concentrations for residents are calculated by the Air Module and used by the Human Exposure Module.

2. **Calculates shower air concentration**. The Human Exposure Module calculates shower air concentration from ground water concentration.

3. **Calculates dose from inhalation of carcinogens.** The Human Exposure Module calculates dose from inhalation of ambient (outdoor) air and shower air for carcinogens. Noncarcinogenic risk for inhalation exposures is based directly on air concentration, not dose; thus, the Human Exposure Module does not calculate inhalation dose for noncarcinogens.

4. **Calculates dose from ingestion of contaminants in media or food**. The Human Exposure Module calculates dose for carcinogens and noncarcinogens from ingestion of soil, ground water, produce (fruits and vegetables), beef, milk, and fish.

5. **Calculates dose from ingestion of contaminants in breast milk**. The Human Exposure Module calculates dose to infants from ingestion of contaminated breast milk. This route of exposure is assessed only for dioxin-like chemicals, and only for infants.

Doses and air concentrations are calculated for each contaminant and site, as well as for each

- **Receptor type.** The module calculates exposures for two types of human receptors: residents and farmers. These are distinguished by how they are located—residents at a single exposure point and farmers on an area representing a farm. Residents are further defined by various kinds of behavior that lead to different profiles of exposure, such as home gardening and recreational fishing. Farmers may also be defined by behavior such as recreational fishing. Human receptor types considered in the 3MRA modeling system are a function of the goals of a particular analysis, and are defined by the receptor data used for the analysis.

- **Age cohort.** The human receptors are divided into five age cohorts (infants under 1 year, children aged 1 to 5 years, children aged 6 to 11 years, children aged 12 to 19 years, and adults) that are used to determine the most appropriate exposure factor data for various pathways, such as body weights, inhalation rates, and consumption rates for various food products.

- **Exposure pathway.** The Human Exposure Module considers nine potential exposure pathways. Depending on the exposure inputs entered into the model, all pathways could be considered for all receptor types in a given simulation. Table 13-1 shows the pathways modeled, and indicates which receptor types are modeled for each pathway by default. All pathways are modeled by default for all age cohorts with two exceptions: the breast milk pathway is modeled only for infants (and no other pathways are modeled for infants), and shower inhalation is modeled only for children aged 12 to 19 years and adults. All of these defaults can be changed by the user through the parameterization of the receptor-specific inputs.

Table 13-1. Default Pathways Considered by Receptor Type

	Receptor Type							
Pathway	**Resident**	**Resident Fisher**	**Home Gardener**	**Home Gardener Fisher**	**Beef Farmer**	**Beef Farmer Fisher**	**Dairy Farmer**	**Dairy Farmer Fisher**
Air inhalation	✓	✓	✓	✓	✓	✓	✓	✓
Shower inhalation	✓[a]	✓[a]	✓[a]	✓[a]	✓	✓	✓	✓
Ground water ingestion	✓[a]	✓[a]	✓[a]	✓[a]	✓	✓	✓	✓
Soil ingestion	✓	✓	✓	✓	✓	✓	✓	✓
Produce ingestion			✓	✓	✓	✓	✓	✓
Beef ingestion					✓	✓		
Milk ingestion							✓	✓
Fish ingestion		✓		✓		✓		✓
Breast milk ingestion	✓	✓	✓	✓	✓	✓	✓	✓

[a] Ground water and shower pathways are considered for residents and home gardeners only if Census data indicate the presence of private wells in the Census block group. All farms are assumed to have a private well.

- **Location.** The Human Exposure Module calculates exposures for residents for a single point. For the current data set, the point is placed at the centroid of each Census block in the area of interest (AOI). The module calculates spatially averaged exposure for farmers at a single farm in each census block group in the AOI that has Census data for farmers and agricultural land areas.

- **Year.** The module calculates exposures for each year of the simulation. The exposures predicted by the Human Exposure Module are reported as a time series

of annual average applied doses or air concentrations. Thus, the equations presented in this section are applied to input data for each year. All temporal averaging for exposure durations exceeding 1 year is done by the Human Risk Module.

13.2 Conceptual Approach

As shown in Table 13-1, receptors are defined by exposures through various pathways; however, not all pathways may be completed at every location for each site, depending on the characteristics at each site (e.g., presence of private drinking water wells or fishable waterbodies). Pathways common to all receptors are inhalation of ambient air and incidental ingestion of soil; residents are assumed to breathe contaminated air and ingest contaminated soil at locations within a site at which contaminant releases are predicted. However, only a subset of receptors have private drinking water wells. This subset is the only group of receptors that could be exposed to contaminated ground water through direct drinking water ingestion and inhalation associated with showering. However, the presence of ground water wells does not necessarily mean that exposures will be estimated by the module. In some situations, the concentration of a contaminant of concern will be zero because of site-specific characteristics. For example, individuals may use drinking water wells and have no exposure because the wells are located outside of the predicted contaminated ground water plume. Similarly, those receptors who use a public water supply (whether from ground water or surface water) drink and shower with treated water that meets all drinking water standards and, thus, are assumed to have no exposure attributable to their water supply.

For the purpose of modeling exposure, the major differences between various receptor types and age cohorts are the specific pathways to which the receptor is potentially exposed and the exposure factors used in the dose calculations. Exposure factors for ingestion rates, inhalation rates, and body weights are randomly selected for each receptor type and each age cohort from distributions can be found in Volume II and are based on data from EPA's *Exposure Factors Handbook* (U.S. EPA, 1997).

With the exception of the shower/bathroom air concentration algorithms, the methodologies and equations used by the Human Exposure Module to convert contaminant concentrations in environmental media or food into human exposure values were obtained from *Methodology for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions* (U.S. EPA, 1998), also known as the MPE methodology, and formerly referred to as the Indirect Exposure Methodology (IEM). The MPE methodology represents the state of the science with respect to providing reliable guidance in the proper conduct of assessments of risks that may result from multimedia, multipathway exposures. The National Center for Environmental Assessment (NCEA) prepared the MPE methodology as an update to EPA's 1990 IEM document. Most of the revisions in the MPE methodology are based on Scientific Advisory Board (SAB) and public comments on IEM. Earlier versions of this document have undergone internal EPA and external peer review. The breast milk exposure pathway algorithms and data were based on MPE and the Dioxin Reassessment (U.S. EPA, 1998, 2000). The shower algorithms were adapted from peer-reviewed sources (McKone, 1987 and Little, 1992).

Exposures from inhalation of ambient air and shower air are expressed differently depending on whether the exposure is being evaluated for a carcinogenic or a noncarcinogenic effect. When inhalation exposures for carcinogenic effects are evaluated, the exposure is expressed as an applied dose in terms of mg/kg-d. For noncarcinogenic effects, the inhalation exposure is expressed as a concentration in mg/m^3. This is because the RfC is in units of mg/m^3 and must be compared to an ambient concentration without explicitly using an inhalation rate or body weight. Ingestion exposures are estimated the same way for carcinogens as for noncarcinogens and are expressed as an applied dose in mg/kg-d.

13.2.1 Calculate Ambient Air Concentrations for Inhalation Exposures

The Human Exposure Module calculates annual average ambient air inhalation concentrations. These are used to calculate dose (also in the Human Exposure Module) for carcinogens and to predict the hazard for noncarcinogens (in the Human Risk Module).

For residents, the air concentration is simply the point estimate for the ambient air concentration at each receptor point, which is calculated by the Air Module. For farms, the Human Exposure Module calculates spatially averaged air concentration over the area of the farm using air concentration data calculated by the Air Module. This concentration is the sum of air vapor and particles (less than 10 μm).

13.2.2 Calculate Shower Air Concentrations for Inhalation Exposures

The Human Exposure Module calculates the annual average air concentration of a contaminant to which the receptor is exposed associated with showering, including both time spent in the shower and time spent in the bathroom immediately after the shower. This concentration is used by the Human Exposure Module for carcinogens to predict dose, and is used directly by the Human Risk Module to predict hazard for noncarcinogens. The primary input is the ground water contaminant concentration calculated by the Aquifer Module.

The concentrations in shower air and bathroom air are related to each other and are determined by solving a system of two coupled differential equations that describe the time-varying changes in average contaminant concentration in the shower and the bathroom, respectively, over the duration of a shower when the shower water is contaminated with contaminant. The change in these air concentrations over time is the result of injecting contaminated spray into an initially clean air environment rather than changes in the inputs over time (e.g., the contaminant concentration in the water, which is constant within a given year). The coupled differential equations are solved using a finite difference approximation. The details of the mathematical derivation of the shower and bathroom air concentrations are described in the U.S. EPA (2000).

The Human Exposure Module calculates the shower and bathroom air concentrations for each of the time steps (e.g., 20 seconds) over the duration of the shower (e.g., 10 minutes) and time spent in the bathroom after the shower (e.g., half an hour). These are then averaged to produce a time-weighted average air concentration for shower-related exposure. This average shower-related concentration is used in subsequent exposure and risk calculations.

13.2.3 Calculate Dose from Inhalation of Carcinogens

Inhalation exposure is calculated for ambient air and shower air for carcinogens. For noncarcinogens, the ambient and averaged shower/bathroom air concentrations described above are used directly by the Human Risk Module.

The applied inhalation dose reflects air concentrations for a single year in the simulation. For each realization (i.e., each time the Human Exposure Module runs), the module will read new data on air concentrations. Although the exposure factors (e.g., body weight, inhalation rate) will remain constant throughout the simulation, the exposure profile will change over time as a function of changing air concentrations.

Inhalation of Contaminated Ambient Air (Carcinogens). Ambient air inhalation exposure is calculated for all receptors that are predicted to be exposed to contaminated ambient air from the Air Module. The following equation is used to calculate an annual average dose from carcinogens inhaled by a human from the ambient air:

$$Dose_{ambient} = \frac{C_{ambient} \times CR_{air}}{BW} \quad (13\text{-}1)$$

where

$Dose_{ambient}$	=	annual average applied dose from ambient air inhalation (mg/kg-d)
$C_{ambient}$	=	total annual average ambient air concentration – vapor phase and particulate-bound (PM10) contaminant (mg/m^3)
CR_{air}	=	inhalation rate for age cohort (m^3/d)
BW	=	body weight for age cohort (kg).

Inhalation of Contaminated Air in the Shower/Bathroom (Carcinogens). The annual average dose from shower inhalation exposures is calculated for all receptors that have wells that are predicted to be in the ground water plume contaminated by a WMU. The governing equation is

$$Dose_{shower} = \frac{C_{shower} \times 1000 \times CR_{air} \times T_{shower} \times Ev_{freq}}{BW \times 1440} \quad (13\text{-}2)$$

where

$Dose_{shower}$	=	applied dose from inhalation associated with showering (mg/kg-d)
C_{shower}	=	average air concentration in bathroom and shower due to contaminated shower water (mg/L)
1,000	=	units conversion factor (L/m^3)
CR_{air}	=	inhalation rate for age cohort (m^3/d)
T_{shower}	=	time exposed during showering (min/event)
Ev_{freq}	=	event frequency (events/d)
1440	=	averaging time to convert to daily exposure (min/d).

The concentration in the bathroom and shower air is calculated as described in Section 13.2.2.

13.2.4 Calculate Dose from Ingestion of Contaminants in Media or Food

The general equation for calculating annual average dose based on ingestion exposure through a single pathway (e.g., ingestion of contaminated drinking water or ingestion of contaminated produce) is as follows[1]:

$$Dose = \frac{Conc \times CR \times Frac}{BW} \qquad (13\text{-}3)$$

where

Dose	=	annual average dose of contaminant taken into the body (mg/kg-d)
Conc	=	annual average concentration of a contaminant in the medium or food item (mg/kg or mg/L)
CR	=	consumption rate of the medium or food item (L/d or g/d)
Frac	=	fraction of the total consumption rate that is contaminated (unitless)
BW	=	body weight (kg).

Consumption rates of food items and body weights vary with age cohort. For some pathways, the consumption rate is expressed per unit of body weight; in those cases, the CR/BW terms are combined into one term, which applies to all age cohorts.

The applied dose reflects media and food concentrations for a single year in the simulation. For each realization (i.e., each time the Human Exposure Module runs), the module will read new data on media and food concentrations. Although the exposure factors (e.g., body weight, food ingestion rate) will remain constant throughout the simulation, the exposure profile will change over time as a function of changing media and food concentrations.

The following subsections provide further detail on the exposure calculation for each pathway. Any modifications to Equation 13-3 required are noted.

Ingestion of Contaminated Soil. Dose from ingestion of contaminated soil is calculated for all resident and farm receptors where soils are predicted to be contaminated. Soil concentrations at residential exposure points are calculated by the Watershed Module. Spatially averaged surficial soil contaminant concentrations for farms are calculated by the Farm Food Chain Module.

Ingestion of Contaminated Drinking Water. Exposure from drinking water ingestion is calculated for all farms and for residential receptors in Census block groups that report private

[1] For some pathways, a unit conversion factor may be needed to convert consumption rate to units that will cancel with the concentration units to produce mg/d. For example, if concentration is in mg/kg and consumption rate is in g/d, a factor of 0.001 is needed to convert g to kg in the consumption rate.

wells and are predicted to be contaminated by a ground water plume from a WMU. It is not calculated for residential receptors in Census block groups that report no private wells.

Ingestion of contaminated drinking water is based only on ground water concentrations, which are calculated by the Aquifer Module. Surface water drinking supplies are assumed to be treated in accordance with drinking water regulations.

Ingestion of Contaminated Produce. Ingestion of contaminated produce is evaluated for farmers and home gardeners, who are residents that grow fruits and vegetables in contaminated air and soils. Some fraction of residential receptors are identified from Census data as home gardeners and are assumed to grow produce, and all farm households are assumed to grow produce. Produce concentrations are an input from the Farm Food Chain Module.

Exposures to homegrown fruits and vegetables are calculated for the following five categories of produce:

- Root vegetables,
- Exposed vegetables,
- Protected vegetables,
- Exposed fruit, and
- Protected fruit.

In addition to classifying produce as a fruit or vegetable (so as to account for different consumption rates), these categories also reflect three classifications—exposed, protected, and root—to account for differences in concentrations due to the different mechanisms by which contaminants can accumulate in edible plant tissues. Specifically, the terms "exposed" and "protected" refer to whether or not the edible portion of a fruit or vegetable that grows above ground is exposed to the atmosphere. For instance, apples are exposed fruits, and oranges are protected fruits. Root vegetables grow below the ground where they are not exposed to the atmosphere, so this distinction is not made for root vegetables, which are contaminated by root uptake of contaminants from the soil. Potatoes are an example of root vegetables. Exposure to contaminated produce is the summation of exposures from each of these five categories.

Consumption rates for produce are normalized to body weight; consequently, they are given in g/kg-d instead of g/d. The consumption rate and body weight terms in Equation 13-3 are therefore replaced by a single body-weight-normalized consumption rate term. All produce consumption rates are given in wet weight (WW). Therefore, the produce concentrations must also be per WW.

Ingestion of Contaminated Beef and Milk. Beef and milk ingestion exposure is calculated for farmers in an AOI when beef and dairy cattle are predicted to be contaminated from the release at a WMU. Only beef farmers are assumed to ingest home-raised beef, and only dairy farmers are assumed to ingest home-produced milk. Contaminant concentrations in beef and milk are generated by the Farm Food Chain Module.

Consumption rates for beef and milk are normalized to body weight; consequently, they are given in g/kg-d instead of g/d. Therefore, the consumption rate and body weight terms in

Equation 13-3 are replaced by a single body-weight-normalized consumption rate term. All beef and milk consumption rates are given in WW. Therefore, the beef and milk concentrations must also be per WW.

Ingestion of Contaminated Fish. The recreational fisher has the same exposures as the resident, the home gardener, and the farmer, but is also exposed through fish ingestion. Recreational fishers may have more than one favorite fishing spot. Therefore, the fisher is assumed to fish from up to three fishable reaches within the AOI, and fish ingestion exposure is calculated using an average fish concentration for those fishable reaches. If fewer than three fishable reaches occur in the AOI, then the average is calculated over all the fishable reaches that exist. If more than three exist, three are randomly sampled out of the full set of fishable reaches. The selection of the three fishable reaches is made twice for each site: once for residential receptors and once for farm receptors. The fish tissue concentration includes both trophic level 3 (TL3) and trophic level 4 (TL4) fish, with each predicted to have a different fish tissue concentration in each of the fishable stream reaches in the AOI. The fish tissue concentrations are predicted in the Aquatic Food Web Module.

13.2.5 Calculate Dose from Ingestion of Contaminants in Breast Milk

Infant exposure occurs through the consumption of contaminated breast milk. To calculate infant exposure through breast milk, the maternal exposure through all pathways is summed, and then the resulting breast milk concentration is calculated as follows:

$$C_{milkfat} = \frac{ADD_{mat} \times f_{am} \times f_f}{(ln2)/t_{1/2}^{b} \times f_{fm}} \qquad (13\text{-}4)$$

where

$C_{milkfat}$	=	annual average concentration in maternal milk fat (mg/kg)
ADD_{mat}	=	average annual total daily dose consumed by the mother (mg/kg-d)
f_{am}	=	fraction of ingested contaminant absorbed by the mother (dimensionless)
f_f	=	proportion of contaminant that is stored in maternal fat (dimensionless)
$t_{1/2}^{b}$	=	biological half-life of contaminant in lactating women (days)
f_{fm}	=	fraction of mother's weight that is fat (dimensionless).

Infant exposures are calculated for eight maternal receptor types: resident, home gardener, beef farmer, dairy farmer, resident/recreational fisher, home gardener/recreational fisher, beef farmer/recreational fisher, and dairy farmer/recreational fisher. The mother is assumed to be an adult (as opposed to a teenager) for the purpose of calculating maternal dose in the infant breast milk pathway.

Infant breast milk exposure is then calculated as

$$Dose_{bmilk} = \frac{[C_{milkfat} \times f_{mbm} + C_{aqueous} \times (1 - f_{mbm})] \times f_{ai} \times CR_{bmilk} \times 0.001}{BW_{infant}} \quad (13\text{-}5)$$

where

$Dose_{bmilk}$	=	annual average applied dose from breast milk ingestion (mg/kg-d)
$C_{milkfat}$	=	annual average concentration in maternal milk fat (mg/kg)
f_{mbm}	=	fraction of fat in breast milk (unitless)
$C_{aqueous}$	=	annual average concentration in aqueous phase of maternal milk (mg/kg)
f_{ai}	=	fraction of ingested contaminant absorbed by the infant (dimensionless)
CR_{bmilk}	=	ingestion rate of breast milk (mL/d)
0.001	=	units conversion factor (kg/mL)
BW_{infant}	=	body weight of infant (kg).

Infant exposure to contaminants via breast milk is calculated only for dioxin-like chemicals. The concentration in milk fat is calculated as shown in Equation 13-4. The concentration in the aqueous phase of breast milk is set to zero because dioxin-like compounds do not accumulate in the aqueous phase. If this pathway were extended to additional constituents, the aqueous-phase concentration might be important. However, data are currently inadequate to extend this pathway to other constituents.

13.3 Module Discussion

13.3.1 Strengths and Advantages

The major strengths and advantages of the Human Exposure Module include the following:

- **Based on peer-reviewed EPA-ORD methodology.** With the exception of the shower/bathroom air concentration models, the methods and equations used by the Human Exposure Module to calculate exposure or applied dose for each environmental media or food are based on Methods for Assessing Health Risks Associated with Multiple Pathways of Exposure to Combustor Emissions (U.S. EPA, 1998) also known as the MPE methodology and formerly referred to as the Indirect Exposure Methodology (IEM). The MPE methodology represents the state of the science with respect to providing reliable guidance in the proper conduct of assessments of risks that may result from multimedia, multipathway exposures. EPA's National Center for Environmental Assessment (NCEA) prepared the MPE methodology as an update to EPA's 1990 IEM document. Most of the revisions in the MPE methodology are based on Scientific Advisory Board (SAB) and public comments on IEM. Earlier versions of this document have undergone internal EPA and external peer review. The breast milk exposure pathway algorithms and data were based on MPE (U.S. EPA, 1998) and the Dioxin Reassessment (U.S. EPA, 2000).

- **Accounts for exposures attributable to a specific microenvironment.** Inhalation exposure to volatile chemicals from contaminated ground water during showering is a specific pathway of concern. Therefore, a specific model that includes volatilization of contaminants during showering and the build-up of a contaminant's concentration in the bathroom during and after a showering activity was incorporated into the Human Exposure Module. The shower and bathroom algorithms were adapted from peer-reviewed sources (McKone, 1987 and Little, 1992).

- **Accounts for spatial variability in exposure across an AOI.** The Human Exposure Module carries forward all spatial information used in the 3MRA modeling system. This provides for the analysis of exposure variability across the AOI. By using census block centroids as the point of analysis, the module accounts for the variability in population across the site; in addition, the number of specific locations across the AOI can range from a few dozen to several hundred.

- **Accounts for different behaviors that may lead to increases in exposure.** Different behavior such as fishing, farming, and gardening are used to identify different groups within the population that may engage in certain activities that can lead to higher exposures. For example, a certain percentage of the population gardens. Most gardeners eat most of the produce that they grow. If these crops are contaminated then the gardening activity increases their exposures over the exposures of their neighbors who might not garden.

- **Accounts for variability in exposure due to differences in age.** Within a specific receptor type, the calculated applied dose varies due to the differences in the exposure factors used for the different age cohorts.

- **Accounts for inter-individual variability within a receptor-type/age cohort.** Statistical distributions were developed for intake rates and body weights for each age cohort within each receptor type. Use of these distributions within the Monte Carlo framework provides a way of assessing the interindividual variability due to exposure factor variability.

13.3.2 Uncertainty and Limitations

Uncertainties and limitations associated with the Human Exposure Module include the following:

- **Human receptors are assumed to be stationary.** It is assumed in characterizing exposure that human receptors both reside and work at the receptor location identified for them during site characterization (i.e., the farm area for farmers or residential exposure area for nonfarmers). The point of exposure is, in general, the Census block centroid for a resident or home gardener and the centroid of a farm for farmers. This assumption may result in either an overestimate or underestimate of exposure, because individuals may reside at the identified

location within the study area but commute to work areas outside of the study area, or commute to more or less contaminated areas within the study area.

- **All residential receptors are assumed to be located at the Census block centroid**. The spatial point estimates of average daily doses for residential receptors assume all receptors in a Census block are located at the centroid of the Census block. Thus, to the extent that some receptors in fact reside or spend appreciable time at more highly contaminated areas within the block, their average daily doses will be underestimated. The converse is also true; that is, the average daily dose at the centroid will overestimate dose in other areas where concentrations are lower. If contaminant concentrations decrease approximately linearly with distance away from the waste management unit (WMU), there is probably little, if any, bias introduced by the centroid assumption. If concentrations decrease nonlinearly (e.g., first-order air deposition), the centroid assumption may overestimate the true average daily dose across the Census block to an unknown extent. The effect of any such bias will also be influenced by the size of the Census block—relatively larger blocks have greater potential for a bias.

- **Only one farm per Census block group reporting farms is modeled**. The number of farms modeled in the study AOI (which affects the farm-receptor population possibly at risk) is the number of Census block groups that make up the AOI that also contain farms. For example, if the AOI includes two Census block groups, and both Census block groups contain farming land use, then two farms will be modeled within the AOI. This could introduce a risk-conservative bias if the AOI does not in fact contain a farm.

- **Estimated exposures due to fish ingestion are subject to random sampling error for both farm and residential receptors.** Residential and farming fishers are assumed to be mobile and catch fish from up to three randomly selected fishable reaches throughout the AOI. These selected reaches may or may not reflect actual preferred fishing locations in the AOI. There is no reason to expect any systematic bias in estimated fish ingestion exposure.

- **Incremental exposures are estimated.** No provision is made for considering background exposures for the purpose of generating aggregate or total risk, hazard quotient, or margin of exposure (MOE) estimates for modeled receptors.

- **No reduction of contaminant concentration in food items is assumed to occur through food preparation.** Washing of fruits and vegetables, and cooking of produce, beef, and milk may reduce contaminant concentrations in foods. This is not accounted for in the model.

13.4 References

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